Mr. Moses Brown.

ESSAY

ON

COMETS.

AN

ESSAY

ON

COMETS,

In TWO PARTS.

PART I.

CONTAINING an Attempt to explain the Phænomena of the TAILS of COMETS, and to account for their perpetual Oppoſition to the SUN, upon philoſophical Principles.

PART II.

POINTING out ſome important Ends for which theſe TAILS were probably deſigned: Wherein it is ſhewn, that, in Conſequence of theſe curious Appendages, COMETS may be inhabited WORLDS, and even comfortable Habitations; notwithſtanding the vaſt Excentricities of their Orbits.

The Whole interſperſed with Obſervations and Reflections on the SUN and primary PLANETS.

By ANDREW OLIVER, JUN. ESQ.

In human Works, though labour'd on with Pain,
A thouſand Movements ſcarce one Purpoſe gain;
In God's, one ſingle can it's End produce;
Yet ſerves to ſecond too ſome other Uſe.
POPE's ESSAY ON MAN.

SALEM, NEW-ENGLAND:
Printed and ſold by SAMUEL HALL, near the Exchange.
MDCCLXXII.

TO

JOHN WINTHROP, LL.D.

HOLLISIAN PROFESSOR

Of the MATHEMATICS, and NATURAL PHILOSOPHY,

AND

FELLOW of the CORPORATION, of *HARVARD-COLLEGE:*

MEMBER of the AMERICAN PHILOSOPHICAL SOCIETY

Of *PHILADELPHIA*;

AND

FELLOW of the ROYAL SOCIETY.

The following ESSAY,

AS an Acknowledgment of the Obligations which reſult from an Initiation, under his Inſtruction, in the Study of thoſe Sciences which more immediately belong to his Province: In Reliance upon his Patronage of a Treatiſe, which owes its Publication to his Candor and Approbation: And, with all due Deference to his ſuperior Judgment; is gratefully inſcribed, by

His Obliged Friend,

And

Moſt Humble Servant,

The AUTHOR.

PREFACE.

THE design of the following Essay was, partly to eradicate some absurd notions which have been handed down from the darkest periods of antiquity, and which are still entertained by some, upon the appearance of a Comet; and to remove the apprehensions which may have been excited in the minds of others, even by the writings of some great men among the moderns: And partly to offer to those who indulge themselves in more abstruse researches after the operations of natural causes, a few hints, the prosecution of which may enlarge the field of philosophical speculation, and open to all a new source for adoration of the wisdom and beneficence of that Being, who has made nothing in vain, and has disposed the various parts of the Universe by weight and measure. *It may therefore be presumed, that, if the Author is so happy as to be understood by the generality of his readers (which he has aimed at throughout the whole) the gentlemen of science will pardon those minute discussions, which* they *may judge unnecessary, and that they will weigh with impartiality the arguments which may be offered for their consideration, overlook any immaterial inaccuracies, which may have arisen through inadvertency, and point out and refute with candour any mistakes which* he *may have fallen into.*

IT is now well known to astronomers that the motions of Comets are regulated by the universal law of gravitation, and that they regard the Sun as the common center of all their motions, equally with the Planets, although they are

more

more numerous, and apparently distinct in species from them. The Planets, since the discovery of the Satellites *or* Moons *which attend some of them, are generally, and with the highest reason supposed to be inhabited Worlds like the Earth.— Whereas it has been thought even by some of the greatest modern astronomers, that the extremes of heat and cold to which Comets are alternately exposed in the different parts of their orbits, are irreconcileable with the notion of their being fit habitations for any material race of beings whatever. They are to this day regarded by the bulk of mankind, either as* portentous meteors, *exhibited only to threaten war, famine or pestilence to the inhabitants of the Earth ; or as* fiery globes *which move thro' the Heavens at random, and might fortuitously come across the Earth in its way, to it is no small detriment, if not to the destruction of its inhabitants ; or lastly as* penal worlds, *ordained to a perpetual chaotic state, whose inhabitants are condemned to be frozen and burned alternately, at their* aphelia *and* perihelia ; *agreeable to* Milton's *idea of the punishment of apostate spirits ; speaking of whom he says,*

" They ———— feel by turns the bitter change
Of fierce extremes, extremes by change more fierce,
From beds of raging fire to starve in ice
Their soft æthereal warmth, and there to pine
Immovable, infix'd, and frozen round
Periods of time, thence *hurried* back to fire."

PARADISE LOST, Book II.

THE first of these opinions was exploded long ago by Seneca ; *who, instead of regarding Comets as transient meteors, on the contrary ranks them with " the eternal works of Nature." The second directly contradicts the*

idea

idea of a divine ſuperintendency, and falls of courſe, in the minds of thoſe who entertain any juſt apprehenſion of the providential care of the great Author and Governor of the Univerſe. And as to the laſt, with what colour of reaſon can we ſuppoſe that the Creator would provide upwards of fifty Worlds (for ſo many different Comets and more there certainly are) ſolely for the puniſhment of the incorrigible inhabitants of five or ſix Planets only? On the contrary does it not redound more to his honour, to conſider theſe bodies as ſo many inhabited Worlds, provided with every neceſſary for the comfortable ſubſiſtance of innumerable inhabitants, rational and irrational, like the Earth? Or as Doctor Young *(ſpeaking of the CREATOR and his works) beautifully expreſſes himſelf;*

" Darts not *HIS* Glory a ſtill brighter Ray,
The leſs is left to *Chaos* and the *Realms*
Of hideous Night?——————

NIGHT THOUGHTS, Night 9.

THE reader will find (in the introduction) that the conſideration of the ſubject, in this light, was firſt ſtarted by Hugh Williamſon, *M. D. of* Philadelphia, *in a treatiſe that was publiſhed in one of the weekly papers; which, as it contained ſome new thoughts, the purſuit of which (it was judged) would tend to the improvement of natural philoſophy, firſt induced the Author to undertake the following Eſſay, upon a ſubject indeed which, till then, he had but little attended to: He therefore hopes that, if any obſervations or reflections ſhall turn up, in the courſe of it, which may merit the attention of his readers, and may have eſcaped the notice of others, they may in ſome meaſure*

atone

atone for the many defects, of which he is apprehensive, and which are submitted to those who have made greater proficiency in natural knowledge, than he pretends to, to rectify.

DIVERS of the Author's friends, who are gentlemen of speculation and learning, perused the Essay in manuscript, upon whose approbation of it, and at whose request, he was induced to consent to its publication: But when the unexpected number of subscribers, and their respectable characters in general, came to his knowledge, his diffidence of its title to their favourable reception was naturally increased, which would have excited in his mind a proportionable reluctance to its appearance abroad, lest their expectations should be disappointed, had he not been fully persuaded, that the greatest candour was naturally to be expected from those who are the best judges of the subject; especially, as the treatise contains nothing more than an attempt to discover some philosophical truths, the knowledge of which may tend to promote the cause of Science, and thereby may possibly be of some service to mankind.

IT was with pleasure He found that Doctor Gowin Knight, F. R. S. had attempted to account for the phænomena of the tails of Comets from the same principle which he has endeavoured to establish in the following pages, viz. a mutual repellency, subsisting between the atmospheres of the heavenly bodies: As the Doctor, when he wrote his treatise, was engaged in the general solution of all the phænomena in Nature, by the help of two universal principles, viz. Attraction and Repulsion, he but slightly touched upon the particular phænomena, now under consideration; accordingly what he says upon the subject is

very

very ſhort, being included within the compaſs of a ſingle corollary, which ariſes out of a long chain of deductions from the ſuppoſed *properties of an* imaginary *repellent fluid, uniformly diſtributed* throughout the infinity of ſpace; *the exiſtence of which, however probable, has never been proved: When the author wrote that part of the Eſſay which is confined particularly to this ſubject, Doctor* Knight's *ſolution was entirely out of his mind, if he had ever ſeen it before. He therefore took a different courſe to eſtabliſh the principle, deducing it from the* known *properties of air, a* real *fluid, the exiſtence of which we are* certain *of, from the* immediate teſtimony of our ſenſes, *as we are of its properties from* innumerable experiments. *This element differs eſſentially from the Doctor's univerſal fluid, which indeed he ſuppoſes to conſiſt of particles mutually repellent, like thoſe of air, but ſo inconceivably rare, that a quantity of it ſufficient to fill the whole ſpace occupied by the ſolar Syſtem, might not weigh one ſingle grain (Knight's Eſſay, page 15): Air on the contrary, is a heavy fluid, the preſſure of which, merely from its gravity, is capable of giving great pain to thoſe who may attempt to ſuſtain its weight, in pneumatical experiments.*

HOWEVER, it does not follow, that if air, conſidered as a fluid ſui generis, *is ſufficient* immediately *to account for the phænomena before us, we ſhould therefore exclude the agency of another, upon whoſe exiſtence and properties (if proved) the properties of air itſelf may poſſibly depend. By ſuppoſing ſuch an univerſal* repellent *fluid, Doctor* Knight *has very curiouſly accounted for many of the phænomena of Nature, which are ſo common as to be but little attended to; ſuch as* fluidity, elaſticity, magnetiſm, *&c. And, whether the mutual repellency of the particles*

particles of air does (as he ſuppoſes) or does not depend upon the preſence of the ſame fluid, the concluſion will equally follow that, The aerial atmoſpheres of the heavenly bodies are mutually repellent.

THE reader is deſired to make the following corrections, the neceſſity and propriety of which were not diſcovered in ſeaſon to ſave him this trouble, viz.

In Page 22, Line 4, for, by the *incumbent* weight of the whole atmoſphere, to read, by the weight of the whole *incumbent* atmoſphere. In Page 38, Line 7, from the bottom, for, all fluids which tend, &c. to read, *every fluid the ſeveral parts of* which tend, &c. In Page 45, Line 8, from the bottom, for, atmoſphere, to read, atmoſpheres. In Page 78, Line 3, for, decreaſe of its atmoſphere, to read, decreaſe *of the denſity* of its atmoſphere. In Page 80, Line 17, to read, whereby the preſence of the Sun *by day*; and in Line 19 of the ſame Page, after the word Comet, to inſert theſe words, viz. *than when it is in the remoter parts of its orbit.*

ESSAY

INTRODUCTION

TO THE

ESSAY.

IN the month of *September*, 1769, during the appearance of a remarkable Comet, Doctor *Hugh Williamson* of *Philadelphia* favoured the publick with a treatiſe on the ſubject of the following Eſſay, which was read before, and publiſhed by order of the Philoſophical Society in that city. This piece contained ſome curious hints, well deſerving the attention of the friends of ſcience: Particularly, that Comets, as well as the Planets, may be *habitable Worlds*; that the comfortable ſtate the inhabitants of the various globes of the ſolar ſyſtem enjoy, may not depend merely upon their ſeveral diſtances from the Sun; and, that although the rays of the Sun may be abſolutely neceſſary to the very exiſtence of planetary heat, yet the temperature of that heat may depend upon the denſities of the atmoſpheres ſurrounding the ſeveral globes; whereby the Comets, even in their aphelia, may be rendered comfortable habitations, by means of the vaſt atmoſpheres which attend them, and which, when they might become detrimental to their inhabitants, as when they are in the neighbourhood of the Sun, are, by the momentum of the Sun's rays, or by ſome other cauſe, thrown off to immenſe diſtances behind them.

The perusal of this treatise occasioned the following attempt to establish the doctrine of the habitability of Comets, advanced therein by Doctor Williamson.

We differ indeed in our hypotheses to account for the phænomena of their tails; but whichsoever may be the true one, all *his* conclusions, relative to the densities of their atmospheres in the various parts of their orbits, may equally follow.

The Doctor's hypothesis, which is the same with *Kepler*'s, supposes the atmosphere of a Comet, by the velocity and consequent momentum of the Sun's rays, to be propelled through immense spaces behind its body, whereby the tail is formed, which is rendered visible by reflecting those rays.

This, it must be confessed, seems to be as natural and easy a solution as any one hitherto offered; and might be embraced as such, had any one experiment ever been produced to prove the rays of light endued with any such power, even upon the most minute corpuscles, or the most rarefied vapor. Sir *Isaac Newton* passes it by with little more than a bare mention, (Princip. under Prop. XLI. Book III.) which, as it is so plausible, is difficult to account for; especially as he fills pages to refute others, that are almost self-evidently absurd. This hypothesis, however, has never been confirmed by any one experiment, although an age has elapsed since *Kepler*'s time, during which experimental philosophy has been at its zenith. Therefore, as Mr. Professor *Winthrop*, in his lectures on Comets, observes, "much stress should not be laid

"upon

" upon it, as we know of no parallel inſtance in na-
" ture to ſupport it." The hypotheſis contained in this Eſſay is founded upon a mutual repellency, which is ſuppoſed to ſubſiſt between the ſeveral atmoſpheres of the heavenly bodies; which is deduced from the repellency of the particles of air, of which the atmoſphere of the earth, and thoſe which ſurround the other globes, are compoſed. That our atmoſphere conſiſts of particles thus repellent, is certain from the whole ſyſtem of pneumaticks, as no one experiment, in that uſeful, inſtructive and entertaining branch of natural philoſophy, can be performed, which does not depend upon this property of AIR. That the Sun and Planets have ſimilar atmoſpheres, will appear in the following pages.

Sir *Iſaac*, after having refuted ſeveral hypotheſes, which had been raiſed by others, to account for the aſcent of Comets tails from the Sun, at length rather hints at, than ſubſtitutes one of his own; as he aſſerts nothing poſitively, but only offers a query for the conſideration of his readers. Therefore it is hoped that nothing here advanced will be conſidered as a *vain*, *raſh* attempt to confute that illuſtrious author. " The
" aſcent of ſmoke in a chimney (ſays he) is owing to
" the impulſe of the air with which it is entangled.
" The air, rarefied by heat, aſcends becauſe its ſpecific
" gravity is diminiſhed, and in its aſcent carries along
" with it the ſmoke with which it is engaged." (Princip. ubi ſupra). To which he adds the following query:
" And why may not the tail of a Comet riſe from the
" Sun after the ſame manner?" Previous to an anſwer to this query, let us conſider more particularly

the

the cauſes of the aſcent of vapors in our atmoſphere. It is indeed beyond doubt, that to the cauſe above aſſigned, by Sir *Iſaac Newton*, is in a great meaſure owing the riſe of ſmoke from common fire; from which, if enkindled in the open air, it will curl up in broad volumes, ſpreading as it riſes; but if confined in a chimney, the rarefied air having but one way to expand itſelf, viz. through the funnel, the more condenſed air in the room below driving it upwards, together with the ſmoke engaged with it, it aſcends in a ſtrait courſe, with a greater velocity, and apparently to a greater height than when unconfined.

But this is not the ſole, nor yet the principal cauſe of the aſcent of vapors in general, but rather an accidental one, which increaſes their velocity when already on the wing. For, *really*, the *cauſa ſine qua non* of their aſcent, in a quieſcent atmoſphere, is the difference of the ſpecific gravities of thoſe vapors, and the air they float in *; the former, being generally lighteſt, continue riſing till they arrive at that region of the atmoſphere in which the denſities of both are equal.—There they gather and form into clouds; there they remain ſuſpended, or are driven by winds in directions parallel to the ſurface of the Earth, until ſome caſual rarefaction of the air, the meeting of contrary winds, or of electrified clouds differently charged, cauſe them, either to condenſe imperceptibly, and fall in dews or gentle rains, or to ruſh more violently together, and precipitate in ſhowers, according to the nature of the cauſe by which they are actuated. The ſmoke of a chimney

* How they are generated, and detached from the ſurfaces of bodies, is a proper ſubject for an enquiry by itſelf, but foreign here.

chimney is for the moſt part lighter than the circumambient air it aſcends through, otherwiſe it would deſcend again as ſoon as it could diſengage itſelf from that column of air which carried it up ; in conſequence of which, life would be very uncomfortable in large, populous cities ; for, at times, the air with us is ſo rarefied that the ſmoke does in fact thus deſcend, and hover juſt above the ſurface of the Earth, to the no ſmall annoyance of the eyes and lungs of thoſe who breathe in ſuch an impure medium. Were it neceſſary, experiments in pneumaticks might be recited, which prove that air, near the ſurface of the Earth, is in general denſer or heavier than the ſmoke and other vapors which float therein ; which are here omitted, as it is preſumed the fact will not be diſputed.

Now, if the tail of a Comet riſes from its head, or rather from the Sun, in the ſame manner as ſmoke does from fire with us, and from a ſimilar cauſe, the æthereal medium, thro' which it aſcends, muſt be nearly of the ſame denſity with the vapors of the tail ; otherwiſe the latter could not float in, nor get ſo entangled with it as to be carried up thereby through diſtant regions of the Heavens ; but that the tails may aſcend to ſuch amazing heights, as ſome of them do, we muſt neceſſarily ſuppoſe their ſpecific gravities much leſs than that of the æther itſelf.

What then becomes of the free celeſtial ſpaces ? in which *Sir Iſaac* ſays,—" not only the *ſolid bodies of* " *the Planets and Comets*, but alſo *the extremely rare va-* " *pors of Comets tails, maintain their rapid motions with* " *great freedom——without reſiſtance.*" (Ibid.) Soon after

after he adds, "—the tails—retaining their own pro-
"per motion" (i. e. the motion they had in common with their heads) "and in the mean time gravitating
"towards the Sun, muſt be revolved in ellipſes round
"the Sun in like manner as the heads are, and by that
"motion always accompany their heads." Now, although the æther may be ſuppoſed ſo extremely rare, as that the ſolid globes may revolve thro' it for many ages, without any ſenſible impediment, or, as *Sir Iſaac* ſays, "above ten thouſand years;" yet, as the tails muſt, upon this hypotheſis, be nearly of the ſame ſpecific gravity with that æther, how can *they* "maintain
"their rapid motions through it *without reſiſtance*, and
"revolve in ellipſes round the Sun together with their
"heads"? That this is utterly impoſſible, appears from the reaſoning of *Sir Iſaac himſelf*, throughout the whole of his VII Section *Principia Book II.* intituled, *Concerning the motion of fluids, and the reſiſtance made to projected Bodies:* According to which reaſoning the projectile motions of theſe vapors would be very ſoon deſtroyed, and the Comet in its regreſs from the Sun would neceſſarily leave them behind as they roſe from the head, in conſequence of the reſiſtance of this æthereal medium: Therefore, whenever the Comet became viſible, after the perihelion, it would have a tail as before, but *reverſed*, appearing, like a lucid beam, to ſtream away from the head *towards* the Sun, till it were confounded with the twilight. But this is contrary to all obſervations; for the projection of a Comet's tail, after its perihelion as well as before, is both really and apparently *from* the Sun, excepting a ſmall deviation towards the parts from whence the Comet laſt came: Which deviation is by no means owing

to

to the reſiſtance of any medium it paſſes through, but is perfectly conſiſtent with its ſeveral parts retaining the motion they had in common with their head when they began to aſcend, and " revolving *freely* in ellipſes " round the Sun together with their head." For, the remote parts of the tail making a larger ſweep through the Heavens than their head, while the latter takes a ſhorter turn round the Sun at its perihelion, muſt neceſſarily be longer in deſcribing the ſame angular motions round the Sun than the globe itſelf; conſequently muſt be deflected from the direct oppoſition to the Sun, and the whole tail be incurvated towards the perihelion poſition lately paſſed; and this upon the ſuppoſition that both head and tail move *freely* through a perfect *vacuum*. This incurvation of the tail leſſens as the Comet recedes from the Sun, 'till at length it recovers its oppoſition as at firſt. Now, as theſe phænomena agree perfectly with the motion of a Comet's tail through ſpaces *void of reſiſtance*, they are utterly inconſiſtent with the ſuppoſition of its moving through a medium of equal or greater denſity than itſelf, or in any other *reſiſting medium* whatever; for according to this celebrated author (Princip. Sect. VII. Book II. Prop. XXXVIII. Cor. 4.) if the head or ſolid globe of the Comet moved in a fluid of the ſame denſity with itſelf, it would loſe half its motion before it could deſcribe the length of two of its diameters, conſequently it would ſoon loſe the whole. The vapors of the tail riſing (upon his hypotheſis) in a medium of nearly the ſame denſity with themſelves, would in like manner, from the reſiſtance of that medium, loſe all the projectile motion they derived from the head, full as ſoon as the head would loſe its own motion in the former caſe.

Sir

Sir *Isaac* concludes said VII Section with the following words, " The *reſiſtance* in every fluid is as the mo-
" tion excited by the projectile in the fluid ; and *can-*
" *not be leſs in the moſt ſubtile æther, in proportion to the*
" *denſity of that æther, than it is in air, water, and quick-*
" *ſilver, in proportion to the denſities of thoſe fluids.*"

Upon the whole, then, it neceſſarily follows, that the æthereal ſpaces through which the *extremely rare vapors of a Comet's tail revolve freely with its head in ellipſes round the Sun*, muſt be perfect *vacuums* as to all the purpoſes of *reſiſtance* ; and conſequently, that the rays of light themſelves in no wiſe impede the freedom of their motion, even when in the neighbourhood of the Sun.

All that is deſired of the reader is, that he will peruſe the following ſheets with candour, and not pronounce ſentence until he has fairly weighed the evidence produced in ſupport of the ſeveral propoſitions therein contained ; upon the ſtrength, or through the deficiency of which, they muſt ſtand or fall.

ESSAY ON COMETS.

PART I.

A COMET conſiſts of two parts which fall under our obſervation, viz. a ſolid, ſpherical, opaque body, which, like the planets, ſhines by reflecting the light of the Sun, and no way differs in appearance from a planetary globe; this is by aſtronomers called the *nucleus*: Alſo a very extenſive atmoſphere; which, from the form it uſually exhibits to us, is called the *tail*, and commonly exhibits a faint beam of light, which diverges as it recedes from the head, and often apparently extends thro' diſtant conſtellations, when it nearly reſembles thoſe momentary corruſcations which ſhoot upwards from the horizon towards the zenith, during the appearance of an *aurora borealis*, or northern light. This tail increaſes in length as the Comet approaches the

Sun, *et vice verſa* ; and its direction is always nearly in oppoſition to the Sun. Sometimes indeed the cometic atmoſphere aſſumes a different form, ſurrounding the nucleus equally on every ſide like a thin cloud or miſt, or, as ſome have fancied, like a buſh of hair ; whence the Comet has been denominated *crinite* or hairy. The latter is the uſual appearance of a Comet when firſt diſcovered in its deſcent toward the Sun, provided the Sun and Comet be in oppoſite hemiſpheres ; and may take place in ſome other ſituations, agreeable to the rules of optics, even when to ſpectators in other parts of our Syſtem, the Comet may exhibit a tail of an enormous length.

It has been ſufficiently demonſtrated by Sir *Iſaac Newton*, Dr. *Halley*, and others, that theſe bodies are, in common with the other globes of the ſolar ſyſtem, ſubject to the law of mutual gravitation, and that they regard the Sun as their common center of gravity, and conſequently move round him in *conic-ſections*, carrying their atmoſpheres or tails along with them. Their orbits differ widely from *circles* on the one hand ; on the other, ſince the diſcovery of the Newtonian method of computing their trajectories from obſervations, they have never been found to deviate into *hyperbolas* ; and though their obſerved places, in the ſmall parts of their orbits in which they are viſible to us, agree with their computed places, upon the ſuppoſition that they move in *parabolas* ; yet, as the periodical revolutions of ſome of them have been aſcertained by their regular returns after certain intervals, it is agreed by aſtronomers, that their paths are truly *elliptical*, though very excentric ;

ſuch

ſuch *ellipſes*, near the extremities of their tranſverſe axes, differing but inſenſibly from *parabolas*. All that is attempted in this Eſſay, is,

1. To account for the phænomena of the tails of Comets, upon philoſophical principles : And then,

2. To point out ſome ends to which they ſeem adapted, and for which they are probably deſigned.

Sir *Iſaac Newton* has ſufficiently proved that theſe tails conſiſt of a fluid matter, extremely rare, emitted from their heads upon their approach to the Sun, which is rendered viſible by reflecting his rays * : But what cauſe there may be exiſting in nature, capable of projecting the cometic atmoſpheres through ſuch immenſe ſpaces, is a queſtion which ſtill remains to be ſolved, no ſatisfactory account having hitherto been offered to the publick. In order therefore, to a rational ſolution of this curious phænomenon, *the tail of a Comet*, the following propoſitions, obſervations, &c. are ſubmitted to the candid peruſal of the reader : Firſt premiſing, that when a ſubject, under conſideration, is in its nature purely phyſical, it is to be preſumed that ſtrict, mathematical demonſtration will not be expected.

We ſhall now endeavour to prove the following propoſitions.

First, That the primary Planets, the Comets, and the Sun, are all ſurrounded with atmoſpheres.

Secondly,

* Princip. Book III. under Prop. XLI.

SECONDLY, THAT theſe atmoſpheres conſiſt of the ſame fluid with the atmoſphere of the earth, viz. Air.

THIRDLY, THAT they are mutually repellent to each other; as the globes they ſurround are in a ſtate of mutual attraction or gravitation.

I. As the proof of the exiſtence of the atmoſpheres of the Sun, Planets and Comets depends upon a variety of aſtronomical obſervations, it is neceſſary to be particular as to each of them.

AND, 1. That the *Earth* we inhabit (which is a Planet vaſtly inferior, both in bulk and ſituation, to ſome others) has one, we have the beſt evidence poſſible, viz. the teſtimony of our ſenſes; beſides, we all know, that the air, which every where ſurrounds the Earth, is eſſential to the breath of life.

2. THAT *Mars* has an atmoſphere, and that very extenſive, has been demonſtrated from the occultation of a fixed Star by that Planet *; as the Star vaniſhed at a diſtance from, or without ever arriving at a viſible contact with his limb; as was obſerved by *Caſſini*, October 1ſt, 1662. The like was obſerved after the ſame occultation, by M. *Roemer*, at Rome, the Star not being viſible after the tranſit till at a diſtance from his limb.

3. *JUPITER*'s belts are in a fluctuating ſtate, as they frequently vary their form, ſize, and ſituation; † which cannot be accounted for, unleſs we ſuppoſe them

* See Smith's Opticks, Vol. II, Page 430. to
† Idem, Page 433.

to be clouds and exhalations, floating in an atmoſphere which ſurrounds his globe. †

4. SOME belt-like appearances were diſcovered in *Saturn* by Mr. *Hadley* through his five-foot reflecter, and by Mr. *Pound* through *Hugenius*'s glaſs, though they appeared very faint, as he is ſo remote ‡; which belts are probably in the ſame fluctuating ſtate as thoſe of *Jupiter*, and ariſe from ſimilar cauſes.

5. THAT *Venus* has an atmoſphere may alſo be inferred from the variable ſpots which have been obſerved upon the face of that Planet, ‖ which are probably of the ſame kind with the belts of Jupiter, or the clouds which float in our own atmoſphere, and, conſequently, have a ſimilar one to ſuſtain them ⸸. But for proof of its exiſtence we need go no further back than the late tranſit of Venus over the Sun's diſc, *anno* 1769; when the atmoſphere itſelf was viſible, and that in different ſituations, to obſervers in diſtant parts. *

6. *MERCURY* is too near the Sun to favour us with ſuch obſervations; but if we ſuppoſe his globe inhabited, he doubtleſs ſtands as much in need of an atmoſphere as any other Planet, and has as important purpoſes to be ſerved thereby.

7. THAT

† Sir Iſaac Newton ſays theſe belts "are formed in the clouds of that Planet." Princip. Book III. Lemma Prop. XXXIX.

‡ S. Opt. Page 441. ‖ Idem, Page 421.

⸸ Were theſe belts, ſpots, &c. really adhering to, and parts of their reſpective globes, they would always appear invariably the ſame, in the ſame ſituations, as thoſe of the Moon do; in which no atmoſphere has yet been diſcovered.

* See Tranſactions of the American Philoſophical Society of Philadelphia, Page 42. Alſo Obſervations by Mr. Benjamin Weſt at Providence, N. E. Page 16.

7. That the Comets are ſurrounded with atmoſpheres is already taken for granted, becauſe ſelf-evident. Sir *I. Newton*, from various obſervations, concludes that their diameters are, one with another, at leaſt equal to ten diameters of their nuclei or ſolid globes. †

8. That the Sun has an atmoſphere, and that proportioned to his amazing magnitude, is rendered highly probable by the macular appearances, or ſpots frequently diſcovered upon his diſc: Which, as they often ſuddenly break out, and as ſuddenly diſappear, and ſometimes vary their ſhapes, even when under the eye of the obſerver; can be no other than huge clouds of ſmoke, or other vapours floating in ſuch atmoſphere; huge indeed! as they frequently exceed the whole ſuperficies of the Earth. Mr. *Derham*, who was peculiarly aſſiduous in obſerving them, has aſſigned a cauſe, to which their phænomena accurately agree. He ſuppoſes them to be immenſe volumes of ſmoak, belched forth by volcanoes or fiery eruptions, which are frequently breaking out upon his ſurface ‡. Theſe ſpots, when large, ſometimes continue during a whole revolution of the Sun round his axis, or about twenty-five days; and it is from the regular returns of ſuch ſpots to the ſame part of his diſc again that this revolution has been determined. But ſuch clouds, were they not ſupported by an atmoſphere, would tumble down again upon the Sun preſently after the exploſions which raiſed them were over,

† See Princip. Book III. Prop. XLI.
‡ See Jones's Abridgment of Philoſoph. Tranſ. Vol. IV. Page 238.

over, as we ſee vapors emitted in an exhauſted receiver, for want of air to ſuſtain them, ſink down to the bottom of the receiver.

II. We ſhall now endeavour to prove that the planetary, cometary, and ſolar atmoſpheres, conſiſt of the ſame elementary fluid with the atmoſphere of the Earth, viz. *AIR*.

Air is a fluid, which when pure is tranſparent, and in the higheſt degree elaſtic, being indefinitely compreſſible and dilatable; which qualities are truly characteriſtic of it, as we know of no other fluid to which they belong.

It may be neceſſary to obſerve here, that upon our globe, which (as already obſerved) is itſelf a Planet, the preſence of air is neceſſary, both to the preſervation of animal life, and to the exiſtance of flame: For in a glaſs receiver, ſmall animals die, and candles go out, immediately upon the air being exhauſted; upon air alſo ſeems to depend the exploſive power of enkindled vapors; for gun-powder itſelf, one of the moſt powerful agents hitherto invented by the art of man, if fired by an hot Iron in vacuo, will conſume away, but never flaſh, nor explode; and it is generally agreed by thoſe who are acquainted with experimental philoſophy, that this vivifying, inflammating quality of air, depends upon its elaſticity, or the active, contrifugal power of its particles, to be conſidered under the next general head. This being premiſed, we proceed to prove,

Firſt, That the atmoſpheres of the ſeveral globes of

of the Syſtem conſiſt of tranſparent fluids: The truth of which will be ſufficiently evident, if we conſider the ſeveral phænomena by which they were diſcovered.

It has already been ſhewn that Mars is ſurrounded with a very extenſive atmoſphere; which, had it not been tranſparent, muſt have eſcaped the notice of aſtronomers during the time of the occultation of the ſtar before mentioned; for were it opaque, it would, by reflecting the Sun's rays, as well as by its want of tranſparency, have hid the Planet itſelf, and by the obſervers have been confounded with it †; in which caſe the moments of the occultation of the ſtar, and of its viſible contact with the limb of the Planet, would have been the ſame; whereas the diſappearance of the ſtar before any ſuch contact could take place, is a demonſtration of the refraction of its rays in a tranſparent medium, with which the Planet is ſurrounded.

The changes which are obſervable in thoſe fluctuating collections of heterogeneous matter, of which the belts and ſpots in the other Planets, and the Sun conſiſt, for the ſame reaſon, could never have been diſcovered, were they not ſuſtained in tranſparent fluids, above the ſurfaces of their reſpective globes.

The tranſparency of the cometic atmoſpheres is undeniable, as their nuclei are frequently ſeen thro' them, although they occupy ſpaces equal to many diameters of the Earth; and the ſmalleſt ſtars are viſible through the

† In like manner, as Sir I. Newton concludes, (Prin. B. III. Lemma IV.) "that "the Earth, if it was viewed from the Planets, would without all doubt ſhine "by the light of its Clouds."

the tails which proceed from, and are only expanſions of them ; in which tails we have ocular demonſtration of a moſt ſurprizing dilatability ; from whence their recompreſſibility and elaſticity may be juſtly inferred.

Secondly, ALTHOUGH there are no obſervations in the records of aſtronomy which prove this elaſticity in the planetary atmoſpheres ; yet, as the Planets are with the higheſt reaſon ſuppoſed to be inhabited Worlds, the preſumption is at leaſt very ſtrong, if ſhort of a demonſtration, that their atmoſpheres are deſigned to anſwer purpoſes every way ſimilar to thoſe which are effected by the atmoſphere of the Earth, and that they are endued with all thoſe properties, which are, with us, neceſſary to the preſervation of animal Life ; conſequently that they are elaſtic, as well as tranſparent, and altogether like our air.

THE atmoſphere of the Sun is, by his exceſſive luſtre, hid from our view ; but if we conſider him as an immenſe flaming globe, kindled up to warm and enlighten the whole ſyſtem, we may well ſuppoſe that he has a large ſhare of that fluid, without which (as before obſerved) ſcarcely any flame can ſubſiſt with us for a moment. Some Authors indeed are of opinion, and not without reaſon, that the Sun is not a body of fire, as commonly ſuppoſed ; Doctor *Knight* in particular, in his curious treatiſe of attraction and repulſion, as two univerſal principles, by which he endeavours to ſolve all the phænomena in nature, ſeems to be of opinion, that the inhabitants of the Sun (if inhabited) are in as much danger of

ſuffering from cold, as from exceſſive heat *. But of whatever ſubſtance the body of the Sun may conſiſt, Mr. Derham has, by his obſervations, put it beyond all reaſonable doubt, that the *maculæ* and *faculæ*, or the darker and brighter ſpots obſervable at times upon the Sun's diſc, are really owing to the burſting of volcanoes; "the *faculæ* being only the appearance of "the flames, after the denſe ſmoke attending the ex-"ploſions is diſſipated, or removed to a diſtance from "them †." Now there is no reaſon to doubt but that, upon our globe, air is as neceſſary to the flames of Ætna and the eruptions of Veſuvius, as to the ſmaller blaze of a candle, or to the exploſion of gunpowder; may we not then rationally conclude, that it is equally neceſſary to thoſe aſtoniſhing volcanoes in the Sun?

It is now proved, as far as the propoſition is in the nature of it capable of proof, that the celeſtial bodies are ſurrounded with atmoſpheres, and that theſe atmoſpheres conſiſt of tranſparent elaſtic fluids, like the air ſurrounding this Earth. It remains that we prove,

* See ſaid treatiſe, Page 58; in which are theſe remarkable Words: Speaking of the Sun and fixed Sars, he ſays, "Their Globes are no longer "frightful Gulphs of Fire, but inhabitable Worlds: Thoſe Philoſophers "who thought them too hot for the Habitation of Salamanders, and "thoſe ſublimer Genii, who thought them to be Hells, will now per-"haps be in Pain, leſt the Inhabitants ſhould freeze with Cold".----- However, Doctor Knight concludes from his own principles, that the Sun has an immenſe aerial atmoſphere condenſed round him; for in the preceding Page 57, he ſays, "The vaſt Weight of the Sun's Atmoſphere muſt make "the Denſity of the *Air* ſo great near the Sun's Surface, that what would "create a Sound ſcarce audible with us, would there produce a very loud "Noiſe."

† See Jones's Abridgment of Phil. Tranſ. before cited.

III. That

III. That the atmoſpheres of the Sun, Planets, and Comets are mutually repellent to each other; as the ſolid globes they ſurround are in a ſtate of mutual attraction or gravitation.

It muſt here be obſerved; that in reaſoning upon gravitation, the great Author of the preſent philoſophical ſyſtem of the Heavens argues downward from the greater to the leſſer, from *Worlds* to *Atoms*; thus, finding by mathematical deductions, compared with aſtronomical obſervations, that all the globes of the ſolar Syſtem, Sun, Planets and Comets gravitate, or have a mutual tendency towards each other, and that this reciprocal attraction is proportional to the quantities of ſolid matter they reſpectively contain; he very juſtly concludes, that every ſingle particle in any one of their ſolid maſſes both attracts, and is attracted by, every other particle of matter, contained in every globe throughout the ſolar Syſtem.*

But as the Heavens exhibit no phænomena from which we can, directly and with equal certainty, infer the exiſtance and univerſal extent of the contrary principle of repulſion, as ſubſiſting between the atmoſpheres of the heavenly bodies; we are here obliged to uſe a contrary method, and to reaſon upward from the powers and properties which, by their effects, we diſcover to belong to thoſe parcels of air upon which we can make experiments; to the effects, which the ſame powers and properties would naturally produce, in thoſe vaſt collections of air, which con-

* *Principia Sparſim.*

ſtitute

ſtitute the atmoſpheres of the ſeveral globes; and if by tracing the neceſſary operations of theſe powers, ſtep by ſtep, we can at length arrive at any of the grand phænomena of nature, we may with the higheſt reaſon conclude, that theſe phænomena are the effects of thoſe powers.

We ſhall therefore endeavour to prove from authors of the beſt credit, or from experiments which any one may try at his leiſure,

1. That there is a mutual repellency ſubſiſting between the particles of air, whereby they continually endeavour to recede from each other; in conſequence of which, that fluid is indefinitely dilatable from the centrifugal activity of its particles, as well as compreſſible by any foreign power.

The honourable *Robert Boyle*, Eſq; found by experiments, that air might be ſo rarefied as to occupy 13769 times the ſpace it fills when in its natural ſtate near the ſurface of the Earth ‡; other experiments prove, that it may be ſo condenſed, as to be contained in $\frac{1}{60}$ part of the ſame ſpace*, therefore multiplying 13769 by 60, it appears, that the cubic ſpace it is capable of filling, under different circumſtances, may be as 826140 to 1. But the cube root of 826140 is 94 nearly; therefore the central diſtances of the particles from each other, as diſcoverable by actual experiment, may be as one to ninety-four, and that from their centrifugal activity.

‡ See Shaw's Abridgment of Boyle, Vol. I. Page 551.
* See Martin's Philoſophical Grammar, Page 178.

Moreover

Moreover, Sir *I. Newton* from experiments concludes this repulsive power to be so great, as that a cubic inch of air, condensed as it is with us, if removed one semidiameter of the Earth above its surface, where it would be free from the pressure of an incumbent atmosphere, would so expand itself by virtue of this power, as to fill the whole sphere of Saturn's orbit; nay he adds, "and far beyond it" †.

2. This mutual repellency of the particles of air is greatly increased by heat. For if a bladder not more than half filled with air, be tied up tight, and laid before the fire, the additional expansive power, which the air contained therein acquires from the heat, will swell the bladder to its utmost extent, and will at length burst it with an explosion.

3. The particles of air, although mutually repellent amongst themselves, are with regard to other matter, in the common state of gravitation or attraction. This is evident from their being condensed in the form of atmospheres round the solid globes of the System, and attending them through all their revolutions.

4. The mutual repellency of the particles of air is indefinitely greater, in proportion to the quantities of repelling matter, than the mutual attraction, subsisting betwixt the solid particles of attracting matter.

The truth of this proposition will appear, at least highly probable, if we consider that the quantity of

† Princip. Book III. under Prop. XLI.

matter

matter contained in our air near the ſurface of the Earth, and which gravitates in common with other matter towards its center, is ſo ſmall, tho' condenſed by the incumbent weight of the whole atmoſphere, that one quart of it weighs no more than eight grains, as appears from experiments; yet ſo great is the repulſive power of its particles, that a ſmall quantity of it, condenſed by art in the barrel of an air-gun, of the ſize and bore of a common fowling-piece, is ſufficient, when permitted ſuddenly to expand itſelf through the tube, to diſcharge a muſket ball, in the ſame manner as fired gun-powder, the noiſe excepted, and with the like fatal effects.

We ſhall now proceed to prove the following propoſition, viz. If two corpuſcles of matter be in a ſtate of mutual repulſion at any given diſtance, as *A. B.* Fig. 1. where they repel each other with a given force, ſay = 1. and this repulſion decreaſes, either as the diſtances *Ac*, *Ad*, *Ae*, *Af*, &c. or as the ſquares, cubes, or any higher powers of thoſe diſtances, increaſe, the extent of that repulſion is indefinite.

For ſuppoſe *A* and *B* to be two ſuch particles repelling each other at the diſtance *A B* with a force = 1. continue the line *A B* indefinitely through the equidiſtant points *c*, *d*, *e*, &c. let the particle *A* be fixed, *B* movable: Let us ſuppoſe this power to decreaſe, 1ſt, ſimply, as the diſtances increaſe; then, if we ſuppoſe the particle *B* to move ſucceſſively through *c*, *d*, *e*, &c. this power, at thoſe ſeveral diſtances, will be

as

as follows, viz. at $c = \frac{1}{2}$, at $d = \frac{1}{3}$, at $e = \frac{1}{4}$, &c. in infinit.

2. If it decreaſe as the ſquares increaſe, it is at $c = \frac{1}{4}$, at $d = \frac{1}{9}$, at $e = \frac{1}{16}$, &c. in inf.

3. If as the cubes, it is at - - $c = \frac{1}{8}$, at $d = \frac{1}{27}$, at $e = \frac{1}{64}$, &c. in inf.

4. If as the biquadrates, it is at $c = \frac{1}{16}$, at $d = \frac{1}{81}$, at $e = \frac{1}{256}$, &c. in inf.

&c. onwards indefinitely.

Now whatever the diſtance aſſigned between the two particles may be, and whatever may be the index of the power which expreſſes the ratio of the decreaſe of their repulſive force, this force will in every caſe be expreſſible by a fraction whoſe numerator is 1, and its denominator equal to the given diſtance, involved according to the index of the given power, as is evident from inſpection of the foregoing fractions as they ſtand. It can never, therefore, become equal to nothing, until the denominator of the fraction becomes infinite, which never can be at any aſſignable diſtance, however great; therefore, the extent of this mutual repulſion is indefinite. Q. E. D.

In mathematical reaſoning, the ſmalleſt quantities are not to be diſregarded, unleſs ſuppoſed ſmaller than any aſſignable, as in fluxions, &c.; for, as all the huge maſſes of the ſolar Syſtem, are compoſed of particles of matter inconceivably ſmall, ſo their mechanical effects upon each other are proportional to the numbers of ſuch component particles they reſpectively contain; and though the mutual effects of

two

two ſingle particles, at any given diſtance, might be indefinitely ſmall, yet we may eaſily conceive, that, when indefinite numbers of ſuch particles are conſolidated into one maſs, and exert their influence from a common center, that *that influence* may be as extenſive as the ſolar Syſtem, and perhaps as the material univerſe. Thus the Sun, by the united attractive force of his conſtituent particles, regulates the motions of the Comets, even at their aphelia, where their diſtances from him confound the human imagination; amounting in ſome of them to many thouſands of millions of miles; yet, at thoſe amazing diſtances from the Sun, they are by his influence retained in their proper orbits, without any deviation, till at length they are brought back to him again, many of them after excurſions of ſome hundreds, and poſſibly ſome of them after thouſands of years; in effecting which every particle of matter in the Sun, however ſmall, bears a part.

On the other hand, the atmoſpheres of the heavenly bodies conſiſt of particles mutually repellent; not conſolidated indeed, as that would be incompatible with the nature of the fluid compoſed of them, but each, in conſequence of the mutual attraction between its conſtituent particles and the globe it ſurrounds, condenſed into a fluid maſs.

In this caſe alſo, though the mutual repellency between two ſingle particles might at a given diſtance be indefinitely ſmall, yet the influence of two ſuch maſſes upon each other, when thus condenſed, may be

be as extenſive as in the former caſe of attraction. The united repulſive force of the particles in each, would in like manner exert itſelf as from their common center.

Let us, for illuſtration of the ſubject, ſuppoſe this repellent power between the particles A and B, Fig. 1, to decreaſe as the ſquares of the diſtances increaſe, then at a diſtance equal to 100000000 A B, or, in other words, ſuppoſe the particles A and B removed *one hundred millions* of times further aſunder than repreſented in the figure, the repulſive force would then be equal to $\frac{1}{10000000000000000}$, or to one *ten-thouſand-million-millionth* part of what it is at the ſimple diſtance A B; which, though ſmall indeed, is yet ſomething, for the ſame diſtance remaining, viz. 100000000 A B, if *ten thouſands of millions of millions* of ſuch particles of equal bulk and repellency were condenſed round the point A as a center, then the repulſive force between the maſs at A and the particle B would be equal to that between the two ſingle particles A and B, at the diſtance A B; once more, ſuppoſe the ſame diſtance, viz. 100000000 A B to remain, and the particle B to have the ſame number of repellent particles condenſed round it, as we have already ſuppoſed, to be condenſed round A; then the repulſive power ſubſiſting between the two maſſes would be *ten thouſands of millions of millions* of times greater than between the two particles *A* and *B*, at the diſtance *A B*.

We have ſeen that air conſiſts of particles thus repellent; nor can we diſcover any bounds to that re-

pellency by any experiments we can make ; and if to other experiments we add Sir *Iſaac Newton*'s reaſoning from ſome of his own, we muſt conclude them indefinitely ſo, and conſequently that their repulſive force decreaſes regularly according to ſome certain ratio of the increaſe of their diſtances, viz. either as the *diſtances ſimply*, or as their *ſquares*, *cubes*, or ſome other *powers* thereof.

It ſeems moſt agreeable to mathematical reaſoning, to ſuppoſe, that all powers, whether attractive or repellent, which act in right lines, to, or from the centers of the attracting or repelling bodies, are proportioned to the inverſe ratio of the *ſquares* of the diſtances of their centers. For, if we conſider theſe powers as repreſented by lines, or rays, converging from every point of the viſible concave of the Heavens to a given point as a center in caſe of attraction, and diverging equally from ſaid center in caſe of repulſion ; and ſuppoſe a corpuſcle of matter to be placed in any part of that ſpace, the number of ſuch rays, intercepted by, and falling upon ſaid corpuſcle, whether they were converging or diverging, would be *in that ratio*, *viz.* inverſely as the *ſquares* of the diſtances of ſaid corpuſcle from ſuch central point. The truth of this aſſertion is capable of the moſt ſimple mathematical demonſtration ; which may be here omitted, as it has been already ſufficiently demonſtrated by others : Upon it indeed depends the truth of Sir *I. Newton*'s poſition, viz. that " the denſity of the Sun's " rays is reciprocally as the *ſquares* of the diſtances " from the Sun" ; from whence he deduces the proportions of light and heat, enjoyed by the ſeveral Planets of the Syſtem.

If

If we conceive ſuch ſuppoſed rays to move with a uniform velocity, and to be attended with any momemtum whatever, whereby, when converging, they impel the corpuſcle to, or repel it, when diverging, from ſaid central point ; as the whole momentum would be proportional to the number of the intercepted rays, the tendency of the corpuſcle to, or from the center, that is, its attraction or repulſion would alſo be in the aforeſaid ratio. That the attraction of gravitation is regulated by this law, aſtronomical obſervations ſufficiently demonſtrate.

But Sir *I. Newton* concludes from experiments, to which all theoretic opinions muſt ever give way, that the mutual repellency between the particles of air is reciprocally as their diſtances only, or "nearly ſo."*

If this be the caſe, the phyſical effects of two particles, and conſequently of two fluid maſſes compoſed of ſuch particles, upon each other, muſt be yet vaſtly greater than if it were reciprocally as the *ſquares* of the diſtances, as we before ſuppoſed, as will evidently appear upon inſpection of the following ſcheme ; in which the *firſt* ſeries repreſents the diſtances, increaſing in arithmetical progreſſion ; the *ſecond*, the repellent force, decreaſing as the diſtances increaſe only ; the *third*, the ſame force conſidered as decreaſing according to the increaſe of the *ſquares* of the diſtances ; thus :

	A	*B*							
Diſtances — —	⊙	1	2	3	4	5	6	7	8
Inverſe ratio of diſt.	⊙	1	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$
--of the ſquares of diſt.	⊙	1	$\frac{1}{4}$	$\frac{1}{9}$	$\frac{1}{16}$	$\frac{1}{25}$	$\frac{1}{36}$	$\frac{1}{49}$	$\frac{1}{64}$

} &c.

* Newt. Princip. Book II. Prop. XXIII.

Here

HERE it is evident that at the diſtance $3\,AB$, if the repellency decreaſed only as the diſtances increaſe, that that force would be equal to $\frac{1}{3}$; but if it decreaſed as the *ſquares* of the diſtances increaſe, it would at the ſame diſtance be equal only to $\frac{1}{9}$; at the diſtance $5\,AB$, in the former caſe, it would be $\frac{1}{5}$, in the latter $\frac{1}{25}$; if at the diſtance $8\,AB$, in the former it would be $\frac{1}{8}$, in the latter $\frac{1}{64}$, &c. But 3 is the ſquare-root of 9 or $\frac{1}{3}$ of $\frac{1}{9}$, $\frac{1}{5}$ of $\frac{1}{25}$, and $\frac{1}{8}$ of $\frac{1}{64}$, &c.

IT therefore follows, that if this repellent force does actually decreaſe ſimply as the diſtances increaſe, the quantity of it at any given diſtance is greater, in the direct ratio of that diſtance, than if it decreaſed in the ratio of the *ſquares* of the diſtances; conſequently, the ſenſible effects of two ſuch fluid maſſes, condenſed, as we have already ſuppoſed, round the particles A and B, would be proportionably more extenſive.

Now, what are the atmoſpheres of the Sun, Planets and Comets, but vaſt collections of theſe repellent particles of air, condenſed round their reſpective globes, by the mutual gravitation ſubſiſting between them, in like manner as we have already ſuppoſed them to be condenſed round the corpuſcles A and B (Fig. 1.)? But if, according to Sir *I. Newton*, ſo ſmall a quantity as a cubic inch of our air, if left to itſelf at the height only of one ſemidiameter of the Earth, might exert this force, ſo as to fill the whole ſphere of Saturn's orbit; it demonſtrably follows, that the atmoſpheres aforeſaid, which conſiſt of huge maſſes of the ſame fluid, may extend their influences as far

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at leaſt ; and though the condenſation of each round its own globe, by virtue of their mutual gravitation, would prevent the ſcattering of its component particles, and confounding itſelf with the atmoſpheres of the neighbouring Planets (as would undoubtedly be the caſe, however great their diſtances might be, did the cauſe of that condenſation ceaſe) yet it is by no means impoſſible, nor yet improbable, that under ſome circumſtances, the phyſical effects of two ſuch atmoſpheres upon each other may become very apparent : For if we ſuppoſe two equal Planets with their atmoſpheres (as *A* and *B* Fig. 2) to paſs near to each other, theſe atmoſpheres being fluid, and that in the higheſt conceivable degree of fluidity, would give way to the leaſt degree of external force, and in conſequence of their mutual repulſion would recede from each other ; but the attractions of their reſpective globes would prevent their leaving them wholly, while each would ſo far retire, as to be depreſſed in the parts next the other, and to ſwell out in the oppoſite parts, changing their ſpherical figures to two oblong ſpheroids as at *C* and *D* (Fig 2.) But this is ſaid upon the ſuppoſition that both the globes and their atmoſpheres are equal, each to the other reſpectively. Whereas, if we ſuppoſe the body *A* to be an immenſe globe like the Sun, having an atmoſphere proportionably large, * and conſequently

* The ſolar atmoſphere is denſe enough at the height of ſeven or eight thouſand miles, or 1-137th part of the Sun's diameter above his ſurface, to ſuſtain thoſe huge clouds of ſmoke which appear to us like ſpots upon his diſc. See Mr. Profeſſor *Winthrop's Cogitata de Cometis*, Page 25. If therefore the atmoſphere of the Sun conſiſts of air, as we have endeavoured to prove it does, and the ſolar clouds and vapors are ſimilar to our own, and, like them, require a certain denſity of air to ſuſtain them in equilibrio, it follows, that the denſity of the air in the Sun's atmoſphere is as great at the height of 7000 miles above

conſequently containing many thouſands, and perhaps ſome millions of times the quantity of this repellent fluid contained in the atmoſphere of *B*; which we may now conſider as a Comet, of equal magnitude with the Earth, but ſurrounded, like other Planets of the ſame ſpecies, with an atmoſphere of great extent, when compared with the magnitude of the globe itſelf; and if we ſuppoſe alſo the viſible effects of the mutual repellency of theſe atmoſpheres to be reciprocally as the quantities of the repellent fluid contained in them, the atmoſphere of the Comet might be prodigiouſly lengthened when in the neighbourhood of the Sun, and repelled to great diſtances behind the nucleus, while at the ſame time, the natural ſpherical form of the Sun's atmoſphere would not be ſenſibly diſturbed by that of the Comet. This reaſoning may be illuſtrated by conſidering the effects of the contrary principle of mutual attraction or gravitation ſubſiſting between the globes themſelves, which effects are ſubjects, both of mathematical computation, and of aſtronomical obſervation: For it is very certain that Comets perform their revolutions round the Sun, in conſequence of this mutual gravitation, in orbits very excentric, and nearly parabolical; whereas it is probable, that the joint efforts of all the Comets which ever appeared, would ſcarcely diſturb the repoſe of the Sun in the center of the Syſtem.

A Comet, in its deſcent through the planetary orbs, approaches the Sun with an accelerating velocity, un-

above his ſurface, as that of our own air, at the height of but 3 or 4 miles above the ſurface of the Earth; a height which our clouds, probably, never exceed. How vaſt then muſt be the extent of the Sun's whole atmoſphere!

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til it arrives at its perihelion ; entering deeper and deeper within the ſpheres, both of the repulſion of the Sun's atmoſphere, and of the activity of his rays ; in conſequence whereof the cometic atmoſphere is continually rarefying during this deſcent, both from the expanſion it undergoes, by means of that repulſion, and from the increaſing heat, which it acquires, as it approaches the Sun, which heat, as already obſerved, contributes greatly to the repellency of the particles of the aërial fluid. By the concurrence of theſe cauſes, if admitted, a tail muſt neceſſarily be formed, the length of which would depend, partly upon the quantity of air contained in the cometic atmoſphere, and partly upon its proximity to that of the Sun, and conſequently would increaſe until the Comet arrived at its perihelion, or rather, from the continuance of the cauſes, until a few days after, which is moſt agreeable to obſervation. When a Comet is at this ſtage of its revolution, if it paſs near the Sun, the tail uſually extends from its head through vaſt regions of ſpace, exhibiting a curious ſpectacle to diſtant Worlds.

If a cometic atmoſphere conſiſted of an *unelaſtic* fluid, and were thus repelled by the atmoſphere of the Sun, it would put on the form of a very oblong ſpheroid, both ends of which would be terminated by a regular curvilinear ſurface as at *A* and *a* (Fig. 3) ; but as it is an elaſtic fluid, whoſe conſtituent particles are, amongſt themſelves, mutually repellent, as ſoon as ever the attraction of the nucleus, which before condenſed them ſpherically round itſelf, is diminiſhed in *any* part of that atmoſphere, by this oppoſite repulſion, the particles

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in *that* part become more and more at liberty to exert their own inherent repellency, which they would at length do *quaquaverſum*, were it not that the repellent power of the Sun's whole atmoſphere, ſo far predominates over their own mutual repellency, as conſtantly to keep them in a direction nearly oppoſite to the Sun's center ; but as this is not ſufficient totally to prevent a lateral dilatation, the tail grows broader and broader, as it extends from the nucleus, while the longitudinal expanſion is rather increaſed than impeded thereby, until the whole train, in a fair view of it, wears nearly the form of a parabolic curve ; the ſeveral parts of which are leſs and leſs diſtinct, as they are further diſtant from the head, until at length, ſpectators ſhall, at the ſame time, differ ten or twenty degrees in their eſtimation of its apparent length, according to the different acuteneſs of their ſight. * (See Fig. 4. *B b.*)

After the perihelion, as the Comet recedes from the Sun, the mutual repulſion of the two atmoſpheres gradually decreaſes, while the mutual gravitation of the Comet and its own atmoſphere proportionably gets the better of it, until at length the exiled atoms are drawn home, and that perhaps without the loſs of a ſingle one ; unleſs the tail ſhould happen to ſweep the ſphere of ſome Planet in its way ; in which caſe, if the atmoſphere of the Planet were large, the mutual repellency of the two would rather occaſion a bifurcation of the cometic atmoſphere than a union or con-

* Sir *I. Newton* in his Princip. ſays, " the Comet of 1680, in the month of " December, emitted a notable tail, extending to the length of 40°, 50°, " 60° *or* 70° and upwards" : The disjunctive *(or)* intimates an uncertainty, of at leaſt 30 degrees, in its apparent length.

fuſion

fuſion of them; but were that of the Planet very ſmall, and did we ſuppoſe that in conſequence thereof, that of the Comet might leave a ſmall portion of its tail behind; ſtill no detriment to us could reaſonably be expected or feared, upon that account, conſidering the amazing rarity of the Comet's Tail. The cometic atmoſphere being gradually re-condenſed round its nucleus as before, would provide it with a ſuitable garment for winter quarters in the remote parts of its orbit; agreeable to the ingenious hypotheſis of Doctor *Williamſon*.

The thickneſs of a Comet's tail, or the diameter of a ſection made perpendicularly thro' it, is amazingly great towards its extremity; the apparent breadth of the tail of the Comet of 1680, where its diſtance from the Earth was equal to the diſtance of the Earth from the Sun, was equal to above three apparent diameters of the Sun *; conſequently the real thickneſs of that part of the tail was about three millions of miles, or between three and four hundred diameters of the Earth, yet, ſays Sir *I. Newton*, "the ſmalleſt Stars were "viſible through it without any diminution of their "luſtre." How inconceivably rare then muſt it have been! Perhaps for ſome thouſands, not to ſay millions of miles, reckoned from its extremity towards its head, it might not have contained more air than a well blown bladder does with us: And that this is not only poſſible, but even probable, appears from Sir *I. Newton*'s computation of the expanſion which a cubic inch

* The Author remembers to have met with this Obſervation ſomewhere, but cannot at preſent recollect where. But it was not far from the truth, if applied to the Comet of 1769.

of our air is capable of, already repeatedly referred to.

So much for the third general propoſition, which the reader will receive or reject, according to the weight of the evidence offered in ſupport of it. It is however hoped that candor will be exerciſed, and that the whole will not be exploded, merely, for want of accuracy in the method, or of perſpicuity in handling a ſubject ſo difficult of acceſs.

A ſhort digreſſion here may not be amiſs, in order to prevent the uncomfortable impreſſions, which the appearance of a Comet is apt to make upon the minds of ſome, and which were greatly increaſed during the appearance of the Comet of 1769, by an injudicious publication in one of the ſouthern newspapers, wherein it was inſinuated, that if that Comet ſhould paſs between the Earth and the Sun, the Earth would paſs through the tail of the Comet; the conſequence of which, the writer ſuppoſed, might be fatal even to the World itſelf. But from the foregoing obſervations it is evident, that ſuch apprehenſions were groundleſs. The ingenious and learned Mr. *Whiſton* has indeed endeavoured to prove, in order to ſupport his *Theory*, that a Comet paſſing near the Earth in its deſcent towards the Sun, occaſioned the univerſal deluge, by leaving behind it a ſufficient quantity of vapors from its atmoſphere and tail, (in which he ſuppoſed the Earth to be inveloped,) when condenſed into rain, to drown the World. He further ſuppoſed that a Comet, in its aſcent from the Sun, might be ſufficiently heated to cauſe a general Conflagration, ſhould it find the Earth in the ſame ſituation.

ſituation. In conſequence of which the fears of many are uſually alarmed, at the appearance of a Comet, by the apprehenſion of ſome grand cataſtrophe. But if the tails of Comets are ſo extremely rare, as we find they muſt neceſſarily be, and as every one muſt be convinced they are, who ever ſaw the Stars ſhining through them; how can we conceive that the Earth in paſſing through one of them, could carry off *oceans* ſufficient to ſubmerge "*all the high hills under the whole Heaven*"? to effect which, many of *our* oceans would, doubtleſs, be neceſſary. On the contrary, it ſeems probable, from the foregoing conſiderations, that the tails of all the Comets which ever appeared, could not, jointly, furniſh water ſufficient for one *ocean* only.—If ſo, the near approach of a Comet muſt be found utterly inſufficient to account for the ſuperior waters of the deluge, or the forty days rain mentioned by *Moſes*; whatever diſorders might otherwiſe be occaſioned in both globes, by their mutual gravitation, in ſuch vicinity. And had the Earth paſſed directly through the midſt of the tail of the Comet of 1769, or of any other, it is not in the leaſt probable, unleſs the Comet had come near enough to injure us upon other accounts, that the Earth could have carried off with it, or that the Comet would have imparted to us, vapors ſufficient, even for a common thunder-ſhower. But this is ſubmitted to the reader; who, perhaps, upon the peruſal of the ſecond part of this eſſay, may be of opinion, that a Comet, in its aſcent from the Sun, is no more calculated to ſet the World on fire, than to drown it in its deſcent. But to return to our ſubject.

HERE

HERE a material objection may naturally ariſe, viz. why ſhould the Comets appear with tails, and thoſe, generally, of enormous lengths, while the Planets, which have atmoſpheres as well as the Comets, are always ſeen without them, even when at equal diſtances from the Sun ?

To this it may be anſwered ; that the atmoſpheres of the Planets are ſo ſmall, in proportion to the globes they ſurround, compared with thoſe of Comets, that whatever may be the cauſe of the tails of the latter ; if the ſame cauſe act upon their ſeveral atmoſpheres, proportionably to the ſpaces they reſpectively occupy, the tails of Comets may appear of aſtoniſhing lengths, while thoſe of the Planets ſhall be totally inſenſible. In other words ; the Planets in ſimilar ſituations ſhall have no tails at all.

THE Earth, as has been repeatedly obſerved, is a Planet, with which, as it is the place of our abode, we are well acquainted : The height of its atmoſphere is generally computed at about fifty miles ; beyond which, its denſity is not ſufficient to reflect the rays of the Sun in the crepuſculum or twilight : The diameter of the Earth is about 8000 miles, the diameter then of the Earth and atmoſphere together is about 8100 miles ; from whence it appears by computation, that the ſpace occupied by the atmoſphere alone is to the ſpace occupied by the Earth alone, as 1 to 26 nearly.

THE diameter of the atmoſphere of a Comet, as before obſerved, is, at a medium, equal to ten times the

the diameter of its nucleus; and, ſpheres being as the cubes of their diameters, the magnitude of a Comet and its atmoſphere together is equal to one thouſand times the magnitude of the Comet alone; conſequently, the ſpace occupied by the atmoſphere, is to the ſpace occupied by the nucleus as 999 to 1.

Let us ſuppoſe a Comet of equal bigneſs with the Earth, having an atmoſphere as above deſcribed, to be ſo ſituated, as that the Sun, the Earth and the Comet, may be in the Angles of an equilateral triangle: Let us ſuppoſe alſo the viſible effect of the repelling power of the Sun's atmoſphere upon thoſe of the Earth and the Comet, to be in proportion to the ſpaces they reſpectively occupy: The magnitudes of theſe atmoſpheres being one to the other as 999 to $\frac{1}{26}$, that is as 25974 to 1; when a ſpectator upon the Earth might ſee the tail of the Comet extend through an arch in the Heavens of 60°; had the atmoſphere of the Earth a tail, ariſing from the ſame cauſe, in proportion to the ſpace it occupied, to a ſpectator upon the Comet it would ſubtend an angle of no more than 0° 0′ 8″ 81‴ or 60° divided by 25974, an angle which the beſt inſtruments could never diſcover in an object ſo dubiouſly defined: In other words, when the Comet would have a tail 60° in length, a Planet at the ſame diſtance from the Sun would have none at all.

The atmoſpheres of the inferior Planets are probably leſs in proportion, and thoſe of the ſuperior, larger than that of the Earth. But this ſubject may more

more properly be introduced in the ſecond part of this Eſſay.

The principle of repulſion by which we have endeavoured to account for the tails of Comets, and their oppoſition to the Sun, may receive further confirmation by conſidering ſome of the phænomena which the atmoſphere of a Comet would exhibit in the neighbourhood of the Sun, were the Sun diveſted of his atmoſphere, or were his atmoſphere deprived of its repellent principle: We ſhall therefore endeavour to prove the following propoſition, *viz.*

WERE the Sun without an atmoſphere, or ſome other appendage in its nature repellent to the atmoſpheres of Comets, and the æthereal ſpaces void of reſiſtance; inſtead of *one* tail, and that always turned from the Sun, every Comet would have *two*; the direction of one being *towards*, the other *from* the Sun, of which the former would be the moſt conſiderable, and both would increaſe as the Comet approached the Sun, from the increaſing gravitation towards him.

FOR though a Comet's atmoſphere in its natural ſtate ſurrounds the nucleus in a ſpherical form, (a form that all fluids which tend to a common center of gravity muſt put on) yet if we ſuppoſe this atmoſphere to be affected by its gravitation towards the Sun, and to conſiſt of an unelaſtic fluid, like water; thoſe parts of this fluid which were neareſt to, and moſt remote from the Sun, would have their gravitation towards the center of the Comet leſſened by the

Sun's

Sun's attraction, and thereby, from a ſpherical form the whole would be changed to an oblong ſpheroid. This is in fact the caſe with our ocean, which is changed from a ſphere to a ſpheroid by the gravitation of the Moon ; the axis of which ſpheroid, revolving round the axis of the Earth in conſequence of the diurnal motion, cauſes the flux and reflux of our ſea. But the atmoſphere of a Comet is indefinitely elaſtic, and thence capable of an unlimited expanſion ; therefore, in proportion as it is in any part elevated above the ſuperficies of the ſphere it occupies when in its natural quieſcent ſtate, ſuch parts are proportionably at liberty to expand themſelves, by virtue of the mutual repulſion of their component particles, which are now in great meaſure freed from that conſtraint which before condenſed them ;* which would change both ends of the ſpheroidal figure, to forms ſimilar to the tails which commonly attend the Comets, being broader as they become rarer towards their extremities, on one ſide and the other : But the tail next the Sun would be the moſt conſiderable, the effects of his attraction on that ſide being greateſt ; and, ſhould the Comet approach near enough to the Sun, a continued aerial ſtream would be formed from one globe to the other, whereby the Sun, by his ſuperior attractive power, would by degrees rob the Comet of its atmoſphere, condenſing the ſame round his own globe, without leaving the Comet a ſufficiency for the purpoſes of life and vegetation in its ſolitary retreat without the planetary ſpheres. But as the Sun has an atmoſphere, repellent to the atmoſpheres of the other heavenly bodies, theſe in-

* See Page 31.

conveniences

conveniences are thereby prevented, and every globe of the ſyſtem retains its own, unimpaired, through every ſtage of its revolution.

That the projection of the tail of a Comet from its nucleus, and its perpetual oppoſition to the Sun, do ariſe from the mutual repellency of the atmoſpheres of Sun and Comet, as we have endeavoured to prove in the foregoing pages; may be confirmed and illuſtrated, if not demonſtrated by electrical experiments.

The electric fluid is an element, as diſtinct from all others which we are acquainted with, as air is from water; and if there be any ſuch thing exiſting in nature, as pure elementary fire, this claims that character, in preference to all others. For fire, in its common form, is ſo far from being a pure element, of itſelf, that the preſence of air is neceſſary to its very being. Whereas the electric fire, in many experiments, acts with greater freedom *in vacuo*, than in the open air. But, different as this wonderful ſubſtance is from all others, we find, that ſome of its properties greatly reſemble thoſe of air, already treated of: And, if the following propoſitions, which are introduced to prove that reſemblance, can be cofirmed by experiments; and it be allowed, that ſimilar cauſes, naturally, produce ſimilar effects; it is preſumed, that the ſolutions of the cometic phænomena, offered in this eſſay, when compoſed with thoſe experiments, will be found not inadequate to the phænomena.

Prop. 1. There is a mutual attraction, ſubſiſting betwixt the electric fluid and common matter; in conſequence

conſequence of which, the former is capable of, and liable to a condenſation round the latter; in the ſame manner as air, by common gravitation, is condenſed round the heavenly bodies, in the form of atmoſpheres.

The truth of this propoſition has been abundantly proved by Doctor *Franklin*, and other writers upon this ſubject: Indeed, the ſucceſs of all our electrical experiments depends upon this property: We may add further, that all the phænomena which have ever been obſerved, in which that element is concerned, from the attraction of ſmall hairs, duſt, &c. in conſequence of the attrition of amber, to the moſt ſevere blaze and irreſiſtable force of lightning; depend in a great meaſure, upon the ſame property.

Prop. 2. Air, as we have ſeen, is a fluid, the particles of which mutually repel each other: So, alſo, is the electric element.

The truth of this propoſition is demonſtrated by the following

EXPERIMENT. I.

Suspend a plate of metal, by wire, from the prime-conductor generally uſed in theſe experiments, and electrify it. On another plate, placed under the former, at the diſtance of three or four inches, put a ſmall quantity of dry ſand, meal, bran, flour, or even the moſt impalpable powder; the particles upon the lower plate, being attracted by, and themſelves attracting the electric atmoſphere, condenſed round the

 under

under ſurface of the upper plate, a beautiful ſhower will enſue: Theſe particles will aſcend to the upper plate; each, by virtue of the aforeſaid attraction, will receive, and condenſe round itſelf, in the form of an atmoſphere, a quantity of this fluid proportional to its capacity; be immediately repelled from it, and deſcend towards the lower plate: But theſe corpuſcles deſcend, diverging from each other, many of them falling wide of the plate, upon the table beneath, to return no more: Which divergency, not only indicates, but is the neceſſary conſequence of, the mutual repellency of the electric atmoſpheres, now condenſed round them. Thoſe that recover the lower plate, having diſcharged their fire, re-aſcend together with thoſe that were left behind at firſt; with them receive a new charge, and return diverging, as before. This operation continues, until moſt of the particles are ſcattered on the table below, few being left between the two plates. Now, as the quantity of the fluid condenſed round each corpuſcle is, probably, proportional to the ſuperficies of the corpuſcle; * and as this experiment will ſucceed with an impalpable powder, if perfectly dry, we may conclude, that the ſmalleſt conceivable portions of the electric matter, when once ſevered, are mutually repellent; from whence we may infer the repellency of its conſtituent particles themſelves.

THIS property is alſo largely treated of by Doctor

* See Doctor *Franklin*'s printed letters page 55. § 15. wherein he aſſerts, that "The form of the electrical atmoſphere is that of the body it ſurrounds."---This he proves by experiments, and from this principle has given a probable ſolution of the operation of points, at a diſtance from the electrified bodies.

Franklin,

Franklin, * and is as neceſſary to moſt electrical experiments, as the former is to all; and, doubtleſs, contributes one half to the amazing rapidity of lightning, to which nothing, ſhort of that of the rays of light, can be compared.

Prop. 3. When two ſmall ſpherical bodies have electrical atmoſpheres, condenſed round them; thoſe atmoſpheres are mutually repellent: As we have endeavoured to prove, from the known mutual repellency of the particles of air, that the atmoſpheres of the heavenly bodies are, amongſt themſelves.

This propoſition naturally reſults from the laſt, and is, in ſome meaſure, involved in it; but, as the experiments now to be produced in ſupport of it, may ſhew us in what manner the electric atmoſpheres act upon, and affect each other, it deſerves a more particular conſideration. For, as theſe atmoſpheres are inviſible, in themſelves, and are diſcoverable, only by their effects, it is neceſſary to charge them with ſome ſubſtances which reflect the rays of light, in order to render them proper ſubjects of obſervation.—But the duſt, powders, &c. uſed in the preceeding experiment, will not anſwer that purpoſe, as they fly off, inſtantly, upon their receiving, and condenſing

* See *Franklin*'s letters page 37. § 5. where he ſays, "Every particle "of matter electrified, is repelled by every other particle, equally "electrified. Thus the ſtream of a fountain, naturally denſe and continual, "when electrified, will ſeparate and ſpread in the form of a bruſh, every drop "endeavouring to recede from every other drop. But on taking out the "electrical fire, they cloſe again." To which may be added, that, if a ſmall tin cup, filled with water, having a ſpout juſt big enough to let out the water by diſtinct drops, be electrified, the water will iſſue from the mouth of the ſpout in a diverging miſt, ſo long as the cup remains charged, but as ſoon as diſcharged again, will fall in diſtinct drops as before.

round

round themſelves a certain portion of the fluid: Inſtead of which, if fine limber threads are run through the balls, in various directions, and their ends cut off at equal lengths, theſe threads, as they cannot eſcape, ſhew, by their ſeveral directions, the tendencies of the electric atmoſpheres of the bodies they adhere to.

This being premiſed, we proceed to the following

EXPERIMENT II.

Let a pellet of cork or pith, thus prepared, be ſuſpended, and electrified; the threads will diverge, equally, every way, from its center as at A Fig. 6. the electric atmoſphere being equally condenſed, upon every part of it, and equirepellent from its center outward. But if two ſuch balls be ſuſpended and electrified, and cauſed to approach each other, the threads of each, which happen to be next to the other, inſtead of ſtanding out every way from the center, as before, will be incurvated towards the line of oppoſition, as at B and C; whereby the reciprocal repulſion of their atmoſpheres is rendered viſible, as the directions of the threads ſhew the tendencies of thoſe atmoſpheres reſpectively; from which it appears, that they recede from each other, as far as the mutual attraction ſubſiſting between each atmoſphere and its own ball, (which at firſt occaſioned a condenſation of the former round the latter,) will permit. But that the atmoſpheres do not wholly fly off, in conſequence of this repulſion, is evident, as the threads continue in the ſame directions, until one, or both be diſcharged.

Query.

Query. Does not this experiment abundantly confirm and illuſtrate the reaſoning in page 29, relative to the paſſage of two Planets, or Comets, attended with large ærial atmoſpheres, by each other ; whoſe mutual effects are repreſented at C and D Fig. 3 ?

We ſhall adduce one experiment more, before we cloſe this ſubject, which may prove as entertaining to him who will be at the trouble of making it, as it is demonſtrative of the principle under conſideration.

EXPERIMENT III.

Provide a wooden ſphere, of four or five inches in diameter (call it A) ; let it be gilt, as the metal will better condenſe the electric fluid upon its ſurface ; alſo a ſmall pellet, of cork, or pith of elder (which call B), ſtrung, as in the laſt experiment, with a few threads, of three or four inches in length : Suppoſe A to repreſent the Sun, B, a Comet ; fix A on the wire of an electric bottle, and ſuſpend B by a ſilken thread from a point, directly over the center of A, ſo as that, when neither of them is electrified, B may reſt againſt A, a little below the level of its center ; and charge both ball and pellet. The mutual repellency of their electric atmoſphere is ſo great, as that *that* of B is thrown off as far from A, as the mutual attraction between the pellet and its atmoſphere will permit ; which attraction is at the ſame time ſo ſtrong, as that, rather than ſuffer a ſeparation, the pellet flies off with its atmoſphere, to a certain diſtance from A, where its natural gravitation to the Earth is juſt balanced by the repellent force of the two atmoſpheres : There B remains

at reſt, while its atmoſphere retires as much farther as poſſible from A, without quitting it wholly; inſtead of which it undergoes a longitudinal dilatation, in oppoſition to the center of A, as the atmoſpheres of Comets do, with regard to the Sun: This is evident from the directions of the threads, which, obſerved in a ſide view, bear a near reſemblance to the tails of Comets. When the pellet is in this ſituation, blow it gently with a bellows, in a direction perpendicular to the line connecting the centers; this will give it a projectile motion, which will be regulated by its common gravitation; and as the center of A is directly under the point from which B is ſuſpended, the latter will be carried round the former, as the center of its motion. Thus will this little Comet perform many revolutions round its electric Sun, and in every one, and through every part of each, the tail of threads will conſtantly maintain its oppoſition to it, as the tails of Comets do to the Sun in the Heavens.

THIS experiment was very agreeably repeated with an artificial Comet, conſiſting of a ſmall, gilt cork ball, with a tail of leaf-gold, about two inches and an half in length; when, during the whole time of the experiment, in which it performed, at leaſt, twenty revolutions, the tail, as nearly as the eye could judge, was conſtantly projected in the line of the oppoſition of the centers of the two balls; the thread, by which the ſmaller one was ſuſpended, either twiſting, or untwiſting, the ſame way, during the whole time. When thus in motion, if we raiſed the globe, the tail was depreſſed; when it was lowered, the tail was elevated; maintaining its oppoſition, in every ſituation.

BUT

But now, from theſe experiments, ſome may, perhaps, be inclined to think, that the electric fluid is the ſole cauſe of the phænomena of the tails of Comets: That the Sun, as it is the grand ſource of light and heat, throughout our ſyſtem, may be the fountain, from which this element, alſo, is ſomehow derived to its ſeveral globes: That Comets, for wiſe ends, unknown to us, have a larger ſhare of this fluid than the Planets; and that, when they approach the Sun's electrical atmoſphere, their own are thereby repelled, as in the foregoing experiments; and appear as lucid, diverging beams, like thoſe which, in the dark, we ſee ſtreaming from electrified points.

This hypotheſis might indeed ſolve the phænomena of the cometic tails, provided the electric atmoſpheres or bodies, charged with that fluid, were viſible in any of our experiments, even when made in the dark: But as that is never the caſe, unleſs the fluid be in motion; and as the proof of the exiſtence of ſuch atmoſpheres, when at reſt, depends ſolely upon their effects upon other ſubſtances, the hypotheſis cannot be admitted. Were this indeed the *true* and *ſole* cauſe of the phænomena, a Planet, near which a Comet might happen to paſs, would be in a ſituation, truly hazardous; for it is evident that the Planets (upon that ſuppoſition) are not accommodated with ſuch vaſt electric atmoſpheres as attend the Comets; conſequently, have not the ſame proportion of that fluid condenſed round them, but far ſhort of it:— Therefore, whenever the electric tail of a Comet paſſed near a Planet, it would be attracted by *it*, be drawn aſide, from its oppoſition to the Sun, towards *it*,

and

and upon *it* discharge the *surplussage* of its fire, that both might have equal, or proportional shares; which discharge, if we consider the snap of a small spark between two cork pellets, and enlarge the idea, proportionably, to that instantaneous cataract of fire which would necessarily take place between two Worlds in similar situations, we may well imagine would give an explosion, which nothing could equal, short of the final voice of an archangel; and, if it were not sufficient to rouse the ashes of the dead, might reduce the living to their primitive dust. But such a catastrophe, we have not the least reason to dread, from the neighbourhood of a Comet, unless we can suppose, that infinite wisdom and goodness would create one world, merely for the destruction of another; as we cannot conceive of any other ends, to which such huge electrical atmospheres could be adapted. Indeed the discharge would be equally fatal to both worlds; as it is certain from electrical experiments, that the effects of a stroke of lightning are the same, whether the flash proceeds from the cloud to the Earth, or is discharged from the Earth into the cloud, both of which have happened during the same thunder-gust; as appears from observations made by Mr. *Kinnersly* and Doctor *Franklin*,* communicated to the Royal Society. But to put this matter beyond all reasonable doubt, we may further observe, that if the phænomena of Comet's tails arose from the same cause, which renders the electric stream visible, when proceeding from a steel point, these tails would shine by their own light, as the electric fluid does, when in motion; whereas, an apparent obscuration or defect, in one of

* *Franklin's* Letters, page 116 and 129.

those

thoſe tails, has been obſerved, which evidently aroſe from the ſhadow of its nucleus, which occaſioned a partial eclipſe of the tail, by intercepting the Sun's rays*: Conſequently, the tail, as well as the head, ſhines with a borrow'd light, and both are viſible, only by reflecting the rays of the Sun.

As the conſideration of the properties of the electric element was introduced, merely, to *illuſtrate* the ſeveral propoſitions, and the concluſions reſulting from them, contained in the foregoing pages; it was thought proper to add thus much upon that ſubject, in order to prevent the framing an hypotheſis from thoſe properties, which, inſtead of removing the fears of the timorous, upon the appearance of a Comet, (which was one deſign of this eſſay,) would naturally tend to increaſe their apprehenſions. Whereas, upon the principles we have endeavoured to eſtabliſh, the tails of Comets appear to be nothing more than air, immenſely expanded and rarefied; through which the Earth might paſs, with the utmoſt ſafety to its inhabitants. And, inſtead of theſe bodies being heralds, ſent forth to denounce the wrath of Heaven, in which light they have been conſidered by the ignorant and ſuperſtitious, of all ages; or the immediate executioners of divine vengeance, as others have apprehended; we ſhall endeavour to prove, in the following pages, that Comets deſerve to be conſidered in a more reſpectable light; and that their tails, however awful and portentous they have been eſteemed

* Hevelii Cometographia Lib. XII. Page 898, quoted by Mr. Profeſſor *Winthrop* in his 2d Lecture on Comets.

by ſome ; may be deſigned for, and are wiſely adapted to, the truly god-like purpoſes, of rendering habitable a vaſt variety of Worlds ; and of affording a *comfortable* ſubſiſtance to innumerable ſpecies of beings, by which they are, probably, inhabited.

ESSAY

ESSAY ON COMETS.

PART II.

AS ancient geographers imagined the polar and equatorial regions, or the frigid and torrid zones of the earth, were uninhabitable, in conſequence of the extremes of heat and cold, to which thoſe climates are expoſed : So, modern aſtronomers have paſſed a ſimilar judgment upon the ſuperior and inferior Planets, eſpecially on *Saturn* and *Mercury* ; concluding, that our water would always boil upon the latter, and be frozen upon the former ; and that merely in conſequence of their different diſtances from the Sun*. Whence it has been naturally concluded, that the textures of their various fluids, and of their inhabitants, to whoſe uſes theſe fluids are adapted, are very different from what they are found to be upon our Earth : And, conſidering the near approaches of moſt Comets *to*, and the vaſt elongations of all their orbits *from* the Sun, it has been generally

* See Newt. Princip. Book III. Prop. VIII. Cor. 4.

ſuppoſed

ſuppoſed, that no material race of beings could ſubſiſt under ſuch amazing viciſſitudes of heat and cold, as thoſe bodies muſt, from their different ſituations, neceſſarily be expoſed to; conſequently that they are uninhabited.

But the concluſiveneſs of this reaſoning depends upon the truth of the following Propoſition; advanced indeed by Sir *Iſaac Newton*; but not ſupported by experiments, which were, with him, the *criterion veritatis*; viz. that, "*The heat of the Sun is as the* "*denſity of his rays, that is reciprocally as the ſquares of* "*the diſtances from the Sun.**"

Here, we are again reduced to the diſagreeable neceſſity, of diſſenting from the opinion of the greateſt GENIUS that ever dignified human reaſon; which, conſidering the juſtly celebrated fame of that illuſtrious author, may be ſtigmatized as ignorance or vanity: But it is hoped that the reader will wave that imputation, if he ſhall judge, upon the whole, that Sir *Iſaac* himſelf would have altered his opinion, upon the evidence which we ſhall produce in ſupport of the contrary poſition: We may, however, lay down this as a maxim, that, in the proſecution of any ſcience, the progreſs of the mind muſt neceſſarily be retarded, in proportion to the *implicit* aſſent we give to the deciſions of any man, however great. We ſhall therefore, without further apology, endeavour to prove that the heat of the Sun, as perceived by us, and as diſcoverable by its effects upon other ſubſtances expoſed to his rays, does not depend upon the denſity of thoſe

* Princip. under Prop. XLI. Book III.

rays

rays *only*, though *they* are neceſſary to the very exiſtence of that heat; but, *equally* upon the *concurrent* operation of another cauſe, which we ſhall preſently conſider; from whence it will follow, that theſe cauſes, wherever they co-exiſt, whether upon the Earth, or upon the heavenly bodies, will naturally produce ſimilar effects.

In the mean time, before we engage in the diſcuſſion of planetary heat, as depending upon the ſeveral diſtances of the Planets from the Sun; it may throw ſome light upon this ſubject if we conſider the portion of that heat which falls to our own ſhare, and the diſtribution of it throughout the various climates of the Earth.

The ſurface of the Earth has, by geographers, been divided into five zones, viz. one *torrid*, including all the regions between the tropics, upon every part of which the Sun ſhines perpendicularly twice every year: Two *frigid*, which are ſituated between the polar-circles and the poles, and endure the rigors of perpetual winter, as the former is always baſking in a ſummer Sun: And two *temperate*, which experience the viciſſitudes of winter and ſummer, and, in ſome parts of them, in their extremes; theſe are ſituated between the *frigid* and *torrid* zones, in both hemiſpheres. In the firſt of theſe, the ſeaſons are much more uniform than in the others, the days and nights being nearly of equal lengths, the year round; and although the heat may, for a conſtancy, be greater therein than in any other climate, yet it is not liable to ſuch great and ſudden changes as are experienced in the temperate zones;

zones ; for, during a whole annual revolution of the earth, the difference of the degrees of heat, experienced in the *torrid* zone, as determined by the thermometer, are not ſo great as thoſe which, ſometimes, happen in the *temperate* zones, within the compaſs of a few hours* : Much more do they fall ſhort of the extremes which are endured in the latter, in the oppoſite ſeaſons of the year.† But what is above aſſerted of the *torrid* zone is to be underſtood only of the low, inhabited and cultivated countries, the mountainous regions with which thoſe climates abound being excepted, for reaſons which will hereafter appear.

THE axes of the ſeveral Planets whoſe diurnal rotations have been diſcovered are inclined, more or leſs, to the planes of their reſpective orbits ; conſequently, their ſuperficies are diviſible into zones and

* One morning, in the winter of 1768, the mercury in *Farenheit's* thermometer was 5° below 0° ; by 11 o'clock the ſame day it had riſen to 30°, and the next day to above 60° ; the difference being 65° in little more than 24 hours. Again, May 30, 1764, when the general election for the choice of councellors, for this province, was held at *Concord*, (a town about 20 miles weſt from *Boſton*) the weather was (for the ſeaſon) extremely hot ; but on the morning of the 1ſt June following, a ſevere froſt cut off all the indian corn, beans and other tender annual vegetables, in that and the towns adjacent, for miles round. And on one Sunday morning, in the winter of 1759-60, a tranſition was made, inſtantaneouſly, from ſevere cold to ſummer heat ; to the great ſurprize of every one, and to the no ſmall terror of many. The buildings ſuddenly ſmoked to ſuch a degree, that, in ſome of the worſhipping aſſemblies at *Boſton*, the people ſuſpected that the neighbouring houſes were on fire ; and there was ſcarcely a perſon, who did not recoil from the heat, at the church doors, at the cloſe of the ſervice.

† One ſummer's afternoon in the year 1760, the thermometer, being expoſed to the open air, in the ſhade, the Mercury ſtood at 102°. At another time, viz. in the winter of 1766-67, the Sun being an hour high in the morning, it was at 9° below 0°. Theſe were probably, as great extremes as have been obſerved in this climate, the difference being 111° by the thermometer.

climates,

climates, correſponding with thoſe of the Earth : And it is, at leaſt, highly probable, that the various climates of each globe, during its periodical revolution round the Sun, experience as great viciſſitudes of heat and cold as thoſe of the Earth : Nor is it unlikely that, in the equatorial regiòns of the different Planets, there may be at the ſame time as great varieties in the degrees of heat they reſpectively enjoy, as there are in the temperate zones of the earth in the different ſeaſons of the year ; but ſuppoſing all this, the inequalities in the diſtribution of heat to the ſeveral Planets and their various climates would vaniſh, when compared with thoſe extremes which they would neceſſarily be expoſed to, at their ſeveral diſtances from the Sun, upon the ſuppoſition that the Sun's heat were as the denſity of his rays ; for were that really the caſe, the heat of Summer upon *Mercury* would be about ſeven times as great as upon the Earth, and above twice as hot as boiling water with us. On the other hand our ſummer heat would be above ninety times greater than that of *Saturn*, the difference being more than ſeven times as great as that between our ſummer heat and the heat of red hot iron* : For it is undoubtedly certain, that the denſity of the Sun's rays is reciprocally as the ſquares of the diſtances from the Sun ; from whence the above concluſions muſt neceſſarily follow, if the heat be proportional to that denſity.

It is certainly then a queſtion well deſerving a philoſophical enquiry ; whether there be not ſome me-

* Sir *I. Newton* concludes from experiments that boiling water is three times, and red hot iron about twelves times hotter than our ſummer heat. Princip. Prop. XLI. Book III.

dium

dium provided in nature, which, being diſtributed in different proportions to the ſeveral Planets, may ſo attemper the heat of the Sun to their reſpective diſtances from him, as that the inhabitants of all may be equally happy in the enjoyment of it; and that one globe may receive as much benefit, and be expoſed to as little injury, from that heat, as any other throughout the ſyſtem. This indeed ſeems to be an object ſo worthy of the attention and providence of the great PARENT of the univerſe, that a philoſophic mind would naturally embrace ſuch an hypotheſis, had it, but, the moſt ſlender evidence to ſupport it. This medium, we ſhall find, is actually provided in the element of air, which is, in various proportions, condenſed round, and conſtitutes the atmoſpheres of the Earth and the heavenly bodies.

As air is an element, to which we, and probably the inhabitants of the other Planets, are more indebted than is generally imagined; a ſhort diſſertation upon ſome of the advantages which accrue to us, and probably to them, from its preſence, may be acceptable to the reader.

AIR is a grand medium in nature, through which an all-bountiful providence conveys to us many of the conveniences, comforts, and delights of life. Upon *Air* depends the aſcent of vapors, and their condenſation into clouds, whence they deſcend in dews and grateful ſhowers, to refreſh and fructify the Earth.—Upon *Air* we depend for the twilight, which affords us an agreeable gradation of ſhades from day to night; without which we ſhould inſtantaneouſly plunge from the

the light of the Sun to midnight darkneſs; and again emerge from total darkneſs to the full luſtre of day; which would be unſufferable to our organs of ſight, upon their preſent conſtructure. *Air* is alſo the vehicle of ſounds, whether articulate or inarticulate; conſequently without it, we ſhould not only be deprived of the artleſs melody of the woods, and of the raptures which accompany the maſterly execution of muſical compoſition; but, which is of infinitely greater importance to us; there could be no language, no communication of ideas, but by dumb ſigns; no liberal arts nor ſciences in the world. Therefore if we could ſubſiſt without this element, all mankind would be like the unhappy few among us who are ſaid to be born deaf and dumb.

It has already been ſhewn from experiments, that *Air* is neceſſary both to the ſupport of animal life, and to the ſubſiſtance of flame: And how far the very being of fire, in any ſhape, and even of heat itſelf, may depend upon it, the reader may judge from the following experiments and obſervations of Mr. *Boyle*, related in *Shaw*'s Abridgement of his Works.

"Coals," ſays Mr. *Boyle*, "being put glowing "into a receiver, in three minutes after beginning "to pump, the fire totally diſappeared.—Other coals "being ſuſpended, in the open air, at the ſame time, "continued burning 'till a great part was reduced "to aſhes*. Lighted match was found more diffi- "cult to put out by exhauſting the air than kindled "charcoal, nevertheleſs in about ſeven minutes the

* Shaw's Boyle, page 419.

"fire

" fire was extinguiſhed, beyond the poſſibility of re-
" covery by re-admitting freſh air." Here we ſee that air is neceſſary to the ſubſiſtance, not only of flame, but of fire that emits no flame at all. To theſe we may add an eaſy experiment, which any perſon may try at his leiſure, without the aſſiſtance of a pneumatic engine, viz. A compoſition may be made of allum and flour, which being well mixed together, reduced to a cinder in a crucible, pulverized, and otherwiſe prepared by a ſecond heat, in a phial ſecured from the free communication of the external air, acquires an igneous quality, which, if the phial be kept ſtopped, it will retain unimpaired, even for many years; nor will it ſhew any appearance of fire more than any other matter confined in the ſame manner; but if at any time a few grains of it be let out upon any combuſtible ſubſtance in the open air, it will by the freſh air be inſtantly changed into fire, and kindle the ſubſtance upon which it falls. This powder is commonly called the black phoſphorus. From a ſmall quantity of it the experiment may be repeated with ſucceſs for years together, provided care be taken, whenever the phial is opened to let out any of the powder, to ſtop it again immediately, to prevent the too free acceſs of the external *Air*. Here we have a ſubſtance which has all the qualities of fire inherent in it, and retains them for a long time, and yet can never exhibit them but upon the admiſſion of freſh *Air*. But to return to Mr. *Boyle*: In page 603 he concludes from experiments, which he had been making in condenſed *Air*, that " the conſumption of mat-
" ter by fire is greater in proportion to the quantity
" of *Air* contained in the (ſame) receiver; or rather
" in

" in a ſtill greater proportion," as he found by ſome ſubſequent experiments. Therefore, as the conſumption of matter by fire, without flame, muſt be proportional to the intenſity of the heat which conſumes it, we may conclude from this laſt obſervation, that the intenſity of the heat in any enkindled ſubſtance, is nearly proportional to the denſity of the ſurrounding *Air*, and depends in a great meaſure upon it. In page 604 Mr. *Boyle* concludes from other experiments, that " fire is more eaſily kindled in *Air* much compreſſed, " than in common *Air*. Now it is certain that, the more intenſe the heat, the quicker the ſame combuſtibles are kindled by it; thus bodies, expoſed to the foci of different burning-glaſſes, will take fire ſooner from ſome than from others, according as the powers of thoſe glaſſes to condenſe the Sun's rays in their foci *(cæteris paribus)* are greater, by which condenſation the heat is proportionably increaſed: But as in theſe experiments, made in condenſed *Air*, Mr. *Boyle* kindled his fire with the rays of the Sun, thus collected in the focus of a burning-glaſs, and found, as above, that the ſame glaſs would more eaſily kindle ſubſtances, in compreſſed *Air*, than in common *Air*, it follows, that, the denſity of the Sun's rays remaining the ſame, the heat with which they were accompanied was increaſed by increaſing the denſity of the *Air*; in like manner as if the denſity of the *Air* had remained the ſame, and the denſity of the rays had been increaſed, by uſing glaſſes of ſtronger powers: To which may be added that Mr. *Boyle* always found it extremely difficult, and ſometimes impoſſible to kindle any ſubſtance whatever in an exhauſted receiver, either by the rays of the Sun, or even by red-hot iron in contact with gun-powder itſelf. The concluſion is obvious to every capacity.

HAVING

HAVING thus exhibited to the reader an imperfect ſketch of the principal uſes to which our Air is ſubſervient; wherein among other things, we have ſeen the neceſſity of its preſence and co-operation in the production of heat by the rays of the Sun, in common experiments: We ſhall now in further proſecution of the ſubject, proceed to prove that the heat of the Sun, as enjoyed by the inhabitants of the Earth in general, depends, not only upon the denſity of the Sun's rays, but, equally, upon the denſity of the ſurrounding atmoſphere. This we ſhall prove from the teſtimonies of travellers of the moſt undoubted reputations who croſſed the ſeas, and undertook the moſt dangerous and fatiguing journies which, perhaps, have ever been performed by man, with no other view than to promote the cauſe of ſcience; particularly *Don George Juan* and *Don Antonio de Ulloa*, and their attendants who were ſent by the Courts of *France* and *Spain* to *South-America*, to meaſure a degree of the meridian under the Equator: In the execution of which commiſſion, they were obliged to take their ſtations, and make their obſervations upon ſome of the higheſt mountains upon the Earth, viz. the *Andes* in the neighbourhood of *Quito*, under the Equinoctial.

IT is well known that the tops of high mountains are at all ſeaſons very cold, and are, for the moſt part, covered with ſnow the year round. But thoſe abovementioned, exhibit a ſcene truly curious; for from their ſummits to the plains below, incluſively, may be found at the ſame time, all the varieties of heat and cold, which are to be met with in every climate of the Earth, at all ſeaſons of the year.*

* See *Ulloa's* voyage to *South-America*, Book VI. Ch. VII.

ONE

One obſervation made by *Don de Ulloa* upon the ſpot, is very remarkable, and much to the preſent point: He ſays, "the region of continual congelation began "upon the ſeveral mountains at the ſame height "above the level of the Sea, as determined by *equal* "*heights of the mercury in the Barometer.*" But Sir *Iſaac Newton* aſſerts, and deduces the certainty of it from "actual experiments," that "as to our own air, "*the denſity of it*" (i. e. at any height) "*is* as the "weight of the whole incumbent air, that is, (ſays he) "*as the height of the mercury in the barometer*".* It therefore follows, that the region of "continual congelation," or perpetual froſt commenced upon all thoſe mountains, where the air was of the ſame denſity. Above that *certain* height, the denſity of the air leſſen'd, and the cold increaſed accordingly in ſeverity, till the tops of the mountains preſented all the horrors of winter, which are to be found in the polar regions. Whereas below *that* height, as the denſity of the air increaſed, from the increaſe of the incumbent preſſure, the heat of the Sun alſo increaſed; till the inhabitants of the plains below ſuffered all the inconveniencies of the torrid zone.

Now, the denſity of the Sun's rays being the ſame in the ſeveral caſes, and the tops of the mountains being above the common region of the clouds, and conſequently enjoying the preſence of the Sun much more than the plains below; it follows, that although the rays of the Sun may be the *ſine qua non*, without which the inhabitants of the Earth would enjoy no heat at all, yet, the degree or *quantum* of their heat depends upon the denſity and co-operation of the aerial medium through which thoſe rays are tranſmitted to them.

As

* See Princip. Book II. Prop. XXII. Schol.

As the proportionality of the Sun's heat to the denſity of his rays, is a point, upon which, as proved or diſproved, many curious queſtions in natural philoſophy may turn, every argument which tends to determine that point will doubtleſs be acceptable to the reader; and if he ſhould be already ſatisfied in his own mind, from the foregoing obſervations, that the heat of the Sun is *not* as the denſity of his rays ſimply, yet it is hoped that he will patiently attend to one argument more, which is drawn from Sir *Iſaac Newton*'s own principles, and naturally reſults from his computation of the amazing, inconceivable degree of heat, which muſt have been acquired by the Comet of 1680, at its perihelion, upon that ſuppoſition; which, though it has never been controverted, but generally allowed to be juſt, and quoted accordingly, muſt, if true, have occaſioned the exhibition of ſome phænomena, which could not have eſcaped the notice of the many curious aſtronomers of that day. According to this great author's calculation, this Comet, by its near approach to the Sun at its perihelion, "acquired a degree of heat *two thouſand times* greater than the heat of red-hot iron*"; but from previous experiments he concludes, that the heat of red-hot iron is but *twelve* times greater than that which dry earth acquires when expoſed to the ſummer's Sun: With what an amazing luſtre then muſt the Comet have glowed, merely from the heat it acquired during its proximity to the Sun! Therefore at its firſt appearance after the perihelion, it muſt have ſhone, not with a borrowed or reflected light, as it did before it arrived at that ſtage, but by its own newly acquired luſtre, far exceeding (perhaps) the brighteſt Star in the Heavens; for if iron heated but *twelve* times more

* Princip. Book III. under Prop. XLI.

than

than dry earth expoſed to a ſummer's Sun, becomes *red-hot*, and from that heat emits a ſplendor, independent of the Sun's rays, we may defy the human imagination to conceive of that ſplendor, when yet increaſed *two thouſand* fold, and exhibited by a globe of equal dimenſions with the Earth. Furthermore, Sir *Iſaac* computes that a globe of red-hot iron equal to the Earth, or the Comet, ſuppoſed of equal bigneſs, would ſcarcely cool in *fifty thouſand years*; therefore the Comet, being *two thouſand* times hotter, if it were a globe of iron, would require 50000 multiplied by 2000, or *one hundred millions* of years to cool in. But if we ſuppoſe the Comet to cool *a hundred* times faſter than an iron globe of the ſame magnitude, equally heated; it could not loſe all its heat under *a million* years *; nay, at the end of *five hundred thouſand* years it would ſtill be *a thouſand* times hotter, and conſequently brighter than red-hot iron. But as the period of this Comet is ſuppoſed to be ſhort of *ſix hundred* years, [ſeveral appearances of Comets in paſt ages being ſuppoſed to be different viſits from the ſame Comet, after intervals of *five hundred and ſeventy five* years;] if at every perihelion it acquired a degree of heat which it could not loſe under *a million* years, and had ſhort of *ſix hundred* years to diſcharge itſelf of the heat acquired at each revolution, how aſtoniſhing upon theſe principles muſt be the accumulations of its heat during thoſe ſeveral revolutions! ſo great!

* This is the duration of heat generally aſſigned to this Comet, after its perihelion. But why a globe of earth ſhould cool an hundred times faſter than a globe of iron, as here ſuppoſed, no where appears, nor ſhould the ſuppoſition be admitted, unleſs we ſuppoſe at the ſame time, that a globe of iron is one hundred times denſer than a planetary globe; if then.

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that one would imagine, that for ages after its perihelion it would be visible merely from its own lustre; and that when, from its distance, its diameter would become insensible, it would still be seen as a lucid point, twinkling among the Stars: Yet so far was this from being the case, that in *three months* from its perihelion, viz. from 8th *December* to 9th *March* it totally disappeared, though the Earth was in a situation to view it for a considerable time after: Sir *Isaac Newton* says "on the ninth and tenth of *February* to the naked "eye the head appeared no more."

THIS Comet, at least its tail, was discovered by Mr. *Flamstead* two days after its perihelion, viz. on the 10th *December*; from which time till its total disappearance, it was constantly observed by astronomers; but none of their observations take notice of any extraordinary brightness it exhibited, more than is usual in the appearance of other Comets. Sir *Isaac* indeed observes, that "in the month of *December*, just after "it had been heated by the Sun, it did emit a much "longer tail, and *more splendid* than in the month of "*November* before, when it had not yet arrived at its "perihelion." But this he asserts of the tail only, for soon after he adds, "the head of this Comet at "equal distances from the Sun and from the Earth, "appeared darker *after* its perihelion than it did *be-*"*fore*": It is true he accounts for it by supposing the "nucleus to be environed by a denser and blacker "smoak than before." But this is difficult to reconcile with what he says a page or two back, when speaking of the same Comet, viz. "by so fierce a "heat, vapors and exhalations, and every volatile "matter

" matter muſt have been immediately conſumed and " diſſipated*". May we not add, and the whole ſolid maſs calcined or vitrified ? Therefore, if that dulneſs in its appearance, after the perihelion, was owing to clouds and vapours, it is evident, from that great author's own reaſoning, that the Comet could not have been expoſed to ſo great an intenſity of heat, in that vicinity to the Sun ; ſince all ſuch heterogeneous exhalations muſt have been conſumed and diſſipated thereby, as faſt as they aroſe from the head ; if indeed any volatile or evaporable matter, or any degree of moiſture whatever could have remained in the head after ſuch an inconceivable ignition. Finally, had the Comet ever acquired ſo great an intenſity of heat, it is probable the inhabitants of the Earth would never have loſt ſight of it to the end of time ; much leſs would it have totally diſappeared in three months after its perihelion.†

* If at the perihelion diſtance of this Comet from the Sun, viz. about 160,000 miles, or 1-6th of the Sun's diameter above his ſurface (according to Sir *I. Newton*), the Sun's heat is ſo fierce, as that " all kinds of vapours and ex- " halations muſt be immediately conſumed and diſſipated thereby", how is it poſſible for thoſe clouds, (for ſuch they undoubtedly are, ſee page 18) which appear, more or leſs, every day, like ſpots upon the Sun's diſk, and float in his atmoſphere, at the height of but 7 or 8000 miles above his ſurface (ſee note * page 29) to remain *undiſſipated* for above twenty days together, as ſome of them moſt certainly do (ſee page 14) ? Or rather, does not the continuance of theſe clouds, for ſo long a time, amount to a demonſtration, upon Sir *Iſaac*'s own principles, that no ſuch heat exiſts, even within the denſer regions of the Sun's atmoſphere.

† If the fixed Stars be ſuppoſed equal in magnitude to the Sun, and the Comet above-mentioned, equal to the Earth ; the period of the Comet to be 575 years, and its body be ſuppoſed ſufficiently luminous to render it viſible in all parts of its orbit ; it appears from Mr. *Bradley*'s determination of the paral- lax of the fixed Stars, after a long ſeries of obſervations (ſee *Smith*'s Opticks, Vol. II. page 449 and onwards), that the apparent diameter of the nucleus of this Comet, muſt be much greater than that of the Stars of the firſt magnitude, even when moſt remote from the Sun and from the Earth.

Sir *I. Newton*, in making his computation of the heat ſuſtained by this Comet, firſt took it for granted, "that the heat of the Sun is as the denſity of his rays," (as we have ſeen before): In the next place, he conſidered the denſity of theſe rays with us, at the mean diſtance of the Earth from the Sun, as a fixed and certain ſtandard, with which the denſity of the rays at every other diſtance might be compared: Then, after expoſing dry earth to the ſummer Sun, he compared the heat contracted thereby, with that of boiling water and red-hot iron, and found by experiments the proportional degrees of heat in them to be nearly as 1, 3, and 12 reſpectively: In the laſt place he conſidered the heat acquired by the dry earth aforeſaid, as the ſtandard of our ſummer heat, and annexed it to the mean denſity of the Sun's rays with us: And upon this foundation he ſeems to have conſtructed his general ſcale of heat for the ſolar ſyſtem. But it is preſumed that the reader is by this time ſatisfied, that the main propoſition upon which that great author's reaſoning was founded muſt fail for want of ſupport, however juſt his concluſions drawn from it may be: For we now find regions of eternal froſt under the equinoctial itſelf, the rigors of which are ſcarcely exceeded in the polar regions; and this, at the height of but two or three perpendicular miles above the common ſurface of the Earth, and where but few clouds interpoſe to hide the beams of the Sun. If therefore we ſuppoſe ourſelves carried up forty or fifty miles higher, or to the very top of the atmoſphere, we may well ſhudder at the idea of ſuch a ſituation, even if expoſed to the unclouded rays of a perpendicular Sun.

We are now naturally led to conſider ſome extenſive purpoſes which the great Author of Nature probably had in view, when he formed the atmoſpheres of, and annexed them to, the ſeveral Planets and Comets of our Syſtem. We have ſeen from indiſputable authority, that the denſity of the Sun's rays alone does not produce a competency of heat, for the comfortable ſubſiſtance of the inhabitants of the Earth, even in its hotteſt climates, but, that a certain denſity of air is equally neceſſary, for theſe rays to operate upon, and to co-operate with them, in promoting the various purpoſes of life and vegetation. This air we are abundantly furniſhed with from the atmoſphere which ſurrounds us, the denſity of which at every height, is proportional to the preſſure of the incumbent fluid. We may conclude from analogy that the atmoſpheres of the other Planets, and of the Comets, are deſigned for, and adapted to the ſame purpoſes for which the atmoſphere of the Earth was originally provided: And if we ſuppoſe the general ſtock of heat, which falls to the ſhare of any Planet, to be in a ratio compounded of the denſity of the Sun's rays and the denſity of the air upon the ſurface of the Planet, it is eaſy to conceive, that theſe globes may be ſeverally furniſhed with ſuch atmoſpheres, as may render them comfortable habitations, whatever their diſtances from the Sun may be. That the heat of the Sun is actually thus diſpenſed to the Planets neceſſarily follows from the experiments and obſervations contained in the foregoing pages, upon the ſuppoſition that they are ſurrounded with aerial atmoſpheres, ſuited to their ſeveral diſtances from the Sun; that they have ſuch atmoſpheres is already proved, and the Creator, has, doubtleſs

doubtleſs wiſely proportioned their reſpective quantities and denſities according to thoſe diſtances.

The *tails* of Comets are nothing more than expanſions of their atmoſpheres, whoſe lengths depend upon their nearneſs to the Sun (as before obſerved) and decreaſe as they recede from the Sun, becoming inviſible to us (generally) before their *heads* diſappear: Therefore we have the higheſt reaſon to conclude that when theſe globes are in the moſt remote parts of their orbits, or at their aphelia, their tails wholly ſubſide, and their atmoſpheres reſume ſpherical forms, like thoſe of the Earth and of the other Planets, ſurrounding their nuclei at equal altitudes in every part; the Sun's atmoſphere being too remote to have any ſenſible effect upon them by its repellency. The air muſt of conſequence be prodigiouſly denſe near the ſurfaces of their globes, being compreſſed by the weight of ſuch a vaſt incumbent fluid; whereby the Sun's rays, though weaker, or leſs denſe than with us in the ratio of the ſquares of the diſtances, may, upon our principles, be rendered as active with them, and as productive of ſuch degrees of heat as are neceſſary for the purpoſes of animal and vegetable life, as with us, or any other Planet of the Syſtem.

But, (as was obſerved by Doctor *Williamſon*,) ſhould theſe atmoſpheres continue of the ſame denſity, through all parts of their orbits, the degrees of heat which their inhabitants muſt undergo at their perihelia would be unſufferable: To prevent which, the great Author of Nature has made ſufficient proviſion; for as they approach the Sun, they are by the repulſion of his atmoſphere (or ſome other cauſe equivalent to ſuch ſuppoſed repulſion) gradually eaſed of that incumbrance,

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the cometic atmoſphere being gradually rarefied and driven behind its body through vaſt ſpaces of the Heavens ; what remains from time to time being more and more rarefied by the increaſing action of the Sun's rays upon it, and repelled as rarefied ; till at length, if they come near enough to the Sun, the inhabitants may have little more than pure æther to breathe in. Thus the Comet of 1769, (than which but few have gone nearer to the Sun) before it arrived at its perihelion, although it projected a moſt aſtoniſhing tail, yet the remaining atmoſphere was denſe enough to hide the nucleus it ſurrounded ; the Comet, when viewed through the beſt teleſcopes, preſenting only a dubiouſly defined luminous appearance : But when it made its re-appearance in the evening about the latter end of *October*, its atmoſphere had undergone ſo great a degree of rarefaction in paſſing its perihelion, that it was ſufficiently pellucid to diſcover the nucleus, which appeared plainly and diſtinctly through it.

May we not then conclude, even with certainty, that as a Comet is perpetually varying its diſtance from the Sun, ſo the denſity of its atmoſphere is continually changing through the various ſtages of its revolution ; and thence, that its inhabitants may at all times enjoy as much benefit, and receive as little injury, from the Sun's rays, as the inhabitants of any other Planet in the ſolar Syſtem ?

As the primary Planets revolve in orbits nearly circular, they have no occaſion for ſuch vaſt atmoſpheres as are neceſſary for the Comets in the remote regions of the Heavens to which they retire ; but are ſurrounded

rounded with ſuch, as infinite wiſdom ſaw beſt ſuited to their ſeveral diſtances from the Sun; ſuch as might have no redundancies to be thrown off in tails at one time more than another; the nearly equal diſtances of each from the Sun, in the ſeveral parts of its orbit, requiring nearly an equal denſity of atmoſphere at all times.

From the premiſes we may conclude, that the atmoſpheres of the inferior Planets are ſmaller, and thoſe of the ſuperior ones larger in *ſome* proportion, than that of the Earth, in order that their denſities near their reſpective ſuperficies, may be ſo proportioned to their ſeveral diſtances from the Sun, as that they may equally ſhare the benefit of his rays. For want of proper aſtronomical obſervations, to determine this point with regard to the other Planets, we can pronounce with certainty only concerning *Mars*: As that Planet is further diſtant from the Sun than the Earth, his atmoſphere, for the reaſons above aſſigned, ought to be larger than our own; accordingly it appears (from the obſervations referred to in Part I. Note * Page 12) that the height of his atmoſphere above his ſurface is at leaſt equal to two thirds of his diameter; which is much greater than that of the Earth, though it falls vaſtly ſhort of thoſe of the Comets. Obſervations of future occultations of fixed Stars by *Jupiter*, *Saturn* and the other *Planets*, made with better inſtruments, may poſſibly determine this point with regard to them alſo.

Several objections may be raiſed againſt the principles advanced in this Eſſay, to all which we hope to give ſatisfactory anſwers. As

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1. It may be objected, that, as the *light* of the Sun is confeſſedly proportional to the denſity of his rays, that is inverſely as the ſquares of the diſtances from the Sun, the inconveniencies ariſing therefrom to the inhabitants of the Comets, at their *perihelia* and *aphelia*, might be nearly as great as thoſe which would ariſe from the Sun's *heat* were it diſtributed in the ſame proportion; or at leaſt, if it did not render the Comets uninhabitable, would make the conditions of their inhabitants, at times very uncomfortable. For example, were the light of the Sun adapted to their various purpoſes, at their *mean diſtances*, at their *aphelia*, they might not enjoy a ſufficiency; and on the contrary at their *perihelia*, the ſplendor would be unſufferable.

This objection, it is preſumed will vaniſh upon a careful attention to the ſtructure of the eyes of terreſtrial animals, whoſe pupils contract or dilate involuntarily, according as the denſity of the rays which paſs thro' them and fall upon their retinas is greater or leſs, whereby more or fewer of thoſe rays are admitted, as may be requiſite for diſtinct, inoffenſive viſion: Thus moſt perſons can ſee to read by candle light near as well as by day light, whereas the quantities of light reflected from objects in the two caſes ſcarely bear any proportion one to the other. But the aperture of the pupil is much greater in the former than in the latter, and more rays in proportion are conſequently admitted. Moreover, there are ſome animals with us which retire to their holes and caves at the approach of day, whoſe purpoſes are as well anſwered by the glimmering

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ing light of the Stars, as thoſe of others are by the preſence of the Sun ; there are yet others which can behold the Sun in his meridian ſplendor, without offence. Now if we only ſuppoſe that the inhabitants of Comets in general have, in the original formation of their optic organs, the power of contracting and dilating their pupils, according to the ſtrength or weakneſs of the light which is tranſmitted through them, we may eaſily conceive, that the rays of the Sun might be no more offenſive to them at one time than at another ; for at their aphelia their pupils might be dilated to their utmoſt extent ; on the other hand, at their perihelia, they might be contracted to phyſical points, if the ſplendor of the Sun ſo required, whereby a proportionally ſmaller quantity would be admitted.

The light of the Sun which the Cometarians enjoy at their aphelia is indeed much greater than we ſhould be apt to imagine ; for let us conſider the Comet of 1680, whoſe period is the longeſt and its aphelion diſtance the greateſt of any one known, being (according to Dr. *Halley)* to the mean diſtance of the Earth from the Sun nearly as 138 to 1 ; but from the reaſoning of Doctor *Smith*, in his optics it appears, that the proportion of our day light to moon light with a full moon, is nearly as 90 000 to 1 ;* and the light of the Sun upon the Comet at its laſt mentioned ſtage is to his light with us but as about 1 to 19000, therefore if we divide 90 000 by 19 000 we ſhall find that Moonlight with us is to Sun-light upon the Comet, nearly as 1 to $4\frac{3}{4}$, and conſequently that the light of the Sun

* Smith's Opticks, Vol. I. Page 29.

enjoyed

enjoyed by the inhabitants of that Comet at its aphelion is nearly five times as great as the light of our full Moon. But it is ſtill much greater upon account of the largeneſs and denſity of the atmoſphere ; for it is certain, that our day light, which is equally diffuſed upon all terreſtrial objects, and renders them viſible ; depends upon the reflection of the Sun's rays, from the atmoſphere, together with the heterogeneous corpuſcles floating in it ; without which all ſuch objects would be as obſcure as at midnight, even with the Sun ſhining in full ſplendor above the horizon ; excepting thoſe upon which the direct rays of the Sun might fall, or ſuch as might be faintly illuminated by the reflection of thoſe rays from neighbouring objects : The Heavens would appear perfectly black, and the ſmalleſt Stars would appear, at noonday, which is prevented, only, by the illumination of the atmoſphere. The beautiful azure, which we obſerve in the Sky, after the atmoſphere is purged of its vapors, by a ſtorm or thunder-guſt, ariſes from the appearance of this black Sky, through the air, which is now become more tranſparent, than when charged with a heterogeneous collection of opaque corpuſcles.

The atmoſpheres of Comets, being much larger and denſer than that of the Earth, reflect a much greater proportion of the Sun's rays ; their hemiſpheres next the Sun muſt therefore be more illuminated, and their day light increaſed, in the ſame proportion ; although the light ariſing from the direct rays of the Sun would be conſiderably weakened thereby.

This reaſoning may be illuſtrated by calling to mind the effects of two great eclipſes of the Sun, one of which happened on the 5th or 6th day of Auguſt, 1766; the other on the 19th day of January, 1768; which effects, moſt perſons among us, whoſe attention was turned that way, may recollect; during the former the air was very clear, and the ſky cloathed in a fine blue, excepting, here and there, where a few ſummer clouds were ſcattered: In the midſt of this eclipſe the air was darkened to ſuch a degree, that, although the Sun ſhone unclouded, a ſickly gloom ſeemed to ſpread over the face of nature. In the latter, (though a much greater eclipſe) the air was full of vapors, the reflection of the Sun's rays from which was ſo copious, as to render it offenſive to the eyes to look at the Heavens, before the eclipſe began, and in the middle of it, the darkneſs occaſioned thereby would ſcarcely have been noticed, had not the eclipſe been known beforehand.

The inhabitants of Comets enjoy another advantage from their great atmoſpheres, which is peculiar to them alone; for, in the hemiſphere turned from the Sun, they can have no dark nights like thoſe of the Planets; but, in conſequence of the reflection of the Sun's rays from thoſe atmoſpheres, muſt be favoured with perpetual twilight if not day light; for a cometic atmoſphere is enlightened by the Sun by night as well as by day, excepting only a column, which is nearly cylindrical at the aphelion, whoſe baſe is a great circle of the Comet, and whoſe altitude is equal to the height of the atmoſphere; which, (conſidering the great

great extent of the latter,) bears but a ſmall proportion to the whole atmoſpheric hemiſphere; this column includes that part of the atmoſphere which is eclipſed by the ſhadow of the globe itſelf, and, if the diameter of the atmoſphere is equal to ten diameters of the globe*, does not contain $\frac{1}{20}$th part of the whole viſible hemiſphere; and is ſtill leſs upon account of the refraction of the Sun's rays, which ſhortens and contracts the cone of the ſhadow. Whence it is probable that the darkeſt nights of the Cometarians, at their aphelia, are much lighter than our brighteſt moonlight nights. But this is ſubmitted to the judgment of the reader.

2. It may further be objected; that if the atmoſpheres of Comets undergo ſuch amazing rarefactions and condenſations, as they neceſſarily muſt, from the alternate projections and retractions of their tails, it is difficult to conceive that they can at all times be fit for the reſpiration of their ſuppoſed inhabitants.

This objection might, perhaps, have remained unanſwerable, had it not been for the genius of that truly great philoſopher Doctor *Edmund Halley*; who, if he was not the original inventor of the *diving-bell*, yet, by a ſagacity peculiar to himſelf, improved it to a degree of perfection, which might, before, have rather been wiſhed for, than expected.† In this *bell* perſons may be let down with ſafety to the bottom of the ſea; but the included air differs in denſity at every depth below the ſurface of the water. At the depth of

* See Page 14.

† See Jones's Abridgment of Philos. Trans. Vol. IV. Page 188, and onward.

thirty-two

thirty-two or thirty-three feet, as the air may occaſionally change, or leſs, in proportion as ſalt water is heavier than freſh, the denſity of the air within the bell is double the denſity of the external air; at double that depth the denſity is triple; at three times, fourfold, and ſo on. Now if the bell be let down without proper precaution, the too ſudden condenſation of the air within, would give the adventurers extreme pain, as they ſometimes found by experience; and ſhould the bell ſink ſuddenly to the bottom of the ſea, the conſequence might be fatal to them; for the ſame reaſon that a ſquare caſe-bottle, filled only with common air above the ſurface of the water, and corked tight, if it were let down with the divers in the bell, would from the increaſing preſſure of the condenſing air without it, be cruſhed inwards, and broken in pieces, in the ſame manner as if the air in the bottle had been exhauſted by an Air-Pump above the ſurface of the water; which effect would be prevented by the ſmalleſt hole in the cork, provided the bell were let down leiſurely, ſo that the air as it condenſed without, might gradually inſinuate itſelf through the hole into the bottle: On the contrary were the bottle corked at the bottom of the ſea, and the bell drawn up from the depth of nine or ten fathoms; before the bell could arrive at the ſurface of the water, the bottle would burſt outwards, from the expanſive force of the condenſed air within it; which might alſo be prevented by a ſimilar precaution. And it is doubtleſs from the latter cauſe that ſome perſons who have aſcended to the tops of high mountains, have been ſeized with reachings, vomitings and other inconve-

niences

niences related by travellers ; the external air of the atmoſphere at ſuch heights being too rare to counteract by its preſſure, the expanſive force of the denſer air which is interſperſed throughout the various veſſels and organs of animal bodies.

But Doctor *Halley* teſtifies from his own experience, that " if the diving-bell be let down (or drawn up) " gradually, about twelve feet at a time with an in- " terval of but a few minutes between, no inconve- " nience would follow" ; as the ſeveral organs of the body would by degrees be inured to the denſity of the air, as it increaſed or decreaſed at the ſeveral depths. The Doctor tells us, that he himſelf was hours together at the bottom of the ſea in nine or ten fathoms of water ; and felt himſelf as well as if he had been all the time on board the ſhip : But the denſity of the air he then breathed, muſt have been more than three times as great as that of the air above the ſurface of the water : In other words, he then breathed in air, compreſſed by the weight of between three and four of our atmoſpheres inſtead of one, and of ten or a dozen ſuch as *Don de Ulloa* breathed in, when upon the tops of the mountains of *Quito*, without any inconvenience. Therefore, it time ſufficient be allowed for the air, included in the ſeveral veſſels of the human body, gradually to contract, expand or otherwiſe accommodate itſelf, to the increaſing or decreaſing denſity of the exterior air ; no bad conſequences or even inconveniencies are to be apprehended, although the difference of denſity be exceeding great.

But by the gradual and regular approach of any Comet to, or receſs from its perihelion, (at and near which its velocity

velocity is greateſt and the conſequent changes in its atmoſphere are moſt ſudden of all) the increaſe or decreaſe of its atmoſphere, is much more regular, uniform, and inſenſible to its inhabitants, than any increaſe or decreaſe of the denſity of the air can be in the diving-bell by Doctor *Halley*'s method; for by the latter, a degree of rarefaction, or condenſation, is effected in a few minutes, which might not take place in the cometary atmoſpheres under ſome days.

PERHAPS enough has been already ſaid to remove every material objection; but if any difficulties yet remain, in the mind of the reader, on account of the vaſt changes which the ſeveral climates in each, and the atmoſpheres of all Comets muſt neceſſarily undergo, in the various parts of their orbits; the following additional obſervations are ſubmitted to his conſideration; which may tend to leſſen thoſe difficulties, if they do not wholly remove them, viz.

As a Comet approaches its perihelion, that hemiſphere of its atmoſphere which is next to the Sun, being more immediately expoſed to his rays, will feel the effects of his neighbourhood ſooner than the oppoſite hemiſphere, and conſequently will be warmed, rarefied, and thrown off behind the Comet by the repulſion of the Sun's atmoſphere, ſooner than the other; the colder and denſer parts of the fluid will of courſe continually flow in from the other ſide of the Comet to ſupply its place, in order to preſerve, as near as may be, an equilibrium; in conſequence of which there will be a conſtant ſucceſſion of the cooler air from thence; whereby the inhabitants on the hemiſphere next the Sun may be continually

continually refreſhed with gales of wind during that vicinity, which would increaſe till the Comet arrived at its perihelion, when their velocity would be greateſt of all; but even then they would not (from this cauſe) blow in ſudden violent guſts like our hurricanes, but ſteadily, unleſs diſturbed by cauſes from within the Comet's atmoſphere; beſides, as the velocity of the current increaſed, the denſity of the fluid would leſſen from the increaſing rarefaction, whereby its momentum might continue nearly the ſame; for this momentum would be in a ratio compounded of the velocity of the fluid and its denſity together; and as the violence of our high winds, and their conſequent effects depend, not upon the velocity, merely, but upon the momentum of the current, this briſk circulation of the cometic air may, (however great we ſuppoſe its velocity) be rather grateful than injurious to the *Cometarians*: And how unfit ſoever the air in ſuch a rarefied ſtate might be for their uſe, if ſtagnant, yet, when thus put in motion, it may be rendered ſufficiently active to anſwer all the purpoſes of reſpiration. This reaſoning is confirmed by daily experience: For it is not an uncommon thing for people of tender frames to faint in a cloſe hot and rarefied air; and as the fan is generally near at hand, it is as common for the by-ſtanders to apply it to their faces, which, by giving a briſk motion to the air, without any alteration of its denſity, generally revives them, in a ſhort time, even when no other remedy is at hand.— This briſk motion of the air would alſo remove or prevent the diſagreeable ſenſations of heat which the

cometary

cometary inhabitants might otherwiſe ſuffer from an expoſure to the Sun's rays at their perihelia: For, if a perſon ſit with his face uncovered before the ſcorching blaze of a common fire, the motion of the air excited by a common fan, even without hiding the blaze from the face, is ſufficient, not only to make the ſituation comfortable, but to change the painful ſenſation to an agreeable coolneſs: As any one will find upon trial.

If we ſuppoſe that every Comet has a diurnal rotation round an axis of its own, the inhabitants may enjoy grateful viciſſitudes, from the alternate abſence and preſence of the Sun; and if we further ſuppoſe this diurnal motion to be performed contrary to its apparent heliocentric motion; the returns of day and night would be quickened as it approached the Sun, from the increaſe of its angular velocity round that globe, whereby the preſence of the Sun, in that neighbourhood, would be of ſhorter duration, upon any one part of the Comet, and his heat might be rendered ſtill leſs irkſome to the inhabitants, on that account. It is true, no diſcovery has been made of any ſuch diurnal motion, but as all the primary Planets, ſo far as our obſervations can reach, are diſcovered to have ſuch motions, we may well be allowed to ſuppoſe that the Comets are not without them; eſpecially now we are endeavouring to prove their habitability, to which this motion is perhaps as neceſſary as to the habitability of the primary Planets. Theſe rotations have been already diſcovered and determined in *Venus*, the *Earth*, *Mars* and *Jupiter*. *Saturn*, though a vaſt globe in itſelf, is ſo remote, and *Mercury* is ſo near the Sun, and ſo very ſmall, that this motion has never

never been discovered in either, by our best instruments, but is justly inferred by analogy ; which method of reasoning will equally extend to the Comets of the System. The diurnal motions of the Planets indeed are performed nearly in the same directions with their annual, both motions in all, as far as they have been discovered, being direct, or from West to East, whereas the diurnal motions of Comets, according to the foregoing supposition, are performed contrary to this rule : But this is no objection against the hypothesis ; for Planets and Comets differ as widely, in almost every other particular ; the annual motions of the former (as now observed,) are all direct, and are apparently confined within the limits of the zodiac, the latter move indifferently in all directions through the Heavens ; the periodical revolutions of the former are made in orbits nearly circular, those of the latter are prodigiously excentric, and nearly parabolical ; all which seem wisely to be ordered, that a multitude of Worlds may exist at the same time, and be enlightened, warmed, and rendered prolific, by the rays of the same Sun, without interfering in their motions, or disturbing the harmony of the System.

To illustrate the reasoning in pages 78, 79, Fig. 5 is added ; in which let S represent the Sun ; to which Comets in general, though perhaps equal in magnitude to our Earth, are, without a *figure*, but as *drops of the bucket*.* Let C represent a Comet with its at-

* In the figure the speck at X and the dots round it, upon the surface of the Sun S, will give a pretty just idea of the comparative magnitudes of the Sun and Comet, and of their atmospheres ; the dots at X representing the Comet's atmosphere, A A A, &c. the atmosphere of the Sun.

 mosphere

moſphere and tail, the dark curve line *c k d g h* on one ſide, and *c i a e f* on the other, may ſerve to give an idea of the motion of a parcel of the cometary air from its more condenſed ſtate behind the Comet at *c*, through its various ſtages of rarefaction and repulſion; as that part of the atmoſphere next the Sun, viz. that in or near the line S *b* which connects the centers of the Sun and the Comet, is rarefied, the denſer air from behind at *c* muſt neceſſarily flow in to preſerve as near as poſſible an equilibrium, and continue ſo to do as long as the rarefaction continues to increaſe. The air next the Sun being thus rarefied, that at *c* would take a turn round the nucleus through *k* and *i*, but before theſe ſeperate parcels came to *d* or *a* the rarefaction would ſo increaſe, that they would begin to aſcend, and as they aſcended, at *a* and *d* they would repel each other; they would ſtill keep riſing by their increaſing rarefaction, through S *b* as through a funnel, and increaſe in their mutual repellency as they receded from the center of the Comet, till at length at *l* and *m* the repellency of the Sun's atmoſphere would compel them to retire through *g h* or *e f* whence they would proceed to the extremity of the tail, the remaining parcels of air in the ſame cometic hemiſphere would take a ſimilar courſe (as repreſented by the faint ſtrokes in the figure) whether their diſtances from the Comet's ſurface were greater or leſs, till at length the rarefaction of the Comet's atmoſphere would become as great, as the repulſive power of the Sun's atmoſphere could effect, or the Comet's vicinity to the Sun, require.—We ſhall offer one obſervation more, for the conſideration of the reader before we cloſe the ſubject, viz.

When

When the air of our atmoſphere appears by the thermometer to be extremely cold, it does not affect the ſenſes ſo diſagreeably, if the atmoſphere be in a calm ſtagnant ſtate, as at other times, when the mercury is ten or even twenty degrees higher, (and conſequently the weather warmer) with a briſk wind, as has been frequently obſerved by thoſe who attend to their thermometers. Now when a Comet is at its greateſt diſtance from the Sun, its atmoſphere, being uniformly condenſed round its globe, might ſettle into a dead calm, for any diſturbances it could receive from without: For whatever influences baneful or ſalutary, the heavenly bodies may reciprocally communicate while in the neighbourhood of each other, the Comets in their aphelia, are removed to ſuch inconceivable diſtances from all the other globes of the Syſtem, that their mutual effects, phyſically conſidered muſt vaniſh. And in ſo calm an atmoſphere, of ſo great a denſity, illuminated by the Sun's rays, the inhabitants of the Comets may, even when moſt remote from the Sun, be as warm, or at leaſt as comfortable as the inhabitants of the Earth, or of any other Planet.

This ſubject cannot be better cloſed than in the words of Doctor *Williamſon*, viz.*

"One of the primary ideas we form of the "ſupreme Being is, that he is the ſource of life, intelli- "gence and happineſs, and delights to communicate "them; the Earth we tread, the water we drink, and "the very air in which we breathe, ſwarm with living

* See Tranſactions of the American Philoſophical Society of Philadelphia.--- Appendix page 30.

creatures,

" creatures, all fitted to their ſeveral habitations.—
" Are we to ſuppoſe that this little globe is the only
" animated part of the creation, while the Comets,
" many of which are larger worlds, and run a nobler
" courſe, are an idle chaos, formed for the ſole pur-
" poſe of being frozen and burnt in turns ?——We
" cannot admit the thought ; the Comets are doubt-
" leſs inhabited."

APPENDIX.

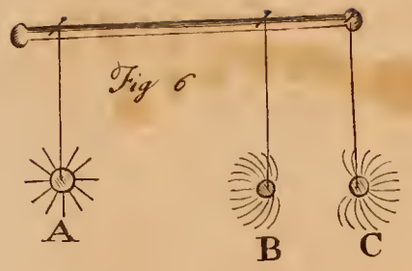


Fig 6

Fig. 1

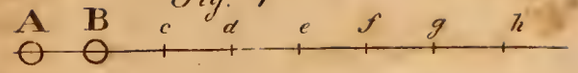


Fig 2

Fig. 3

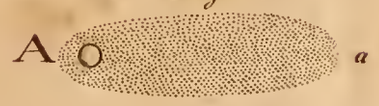


Fig. 4

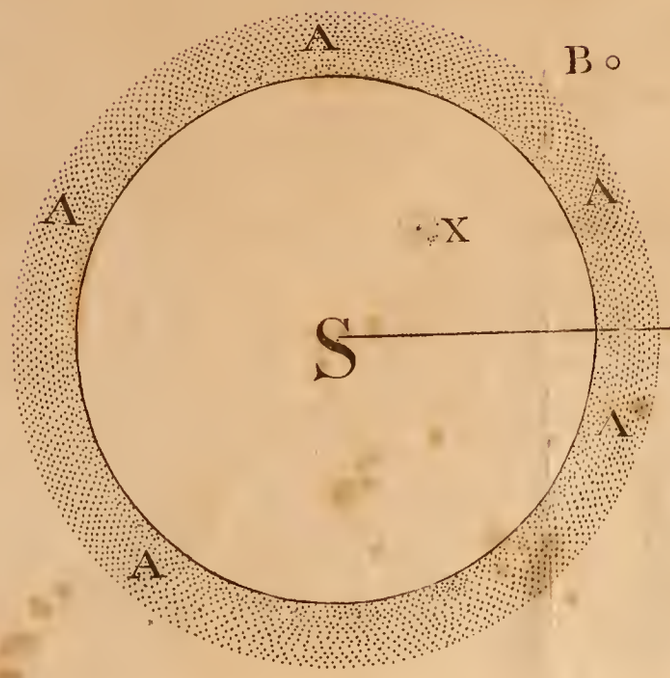
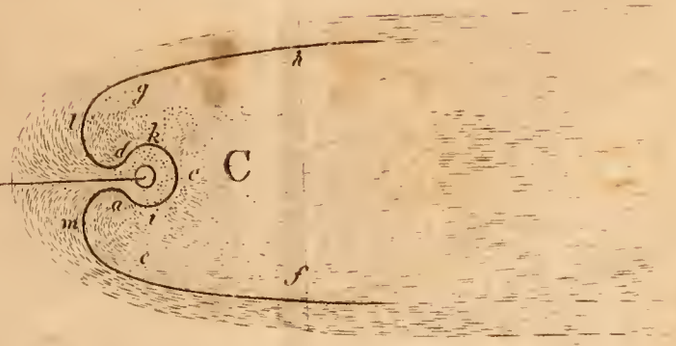


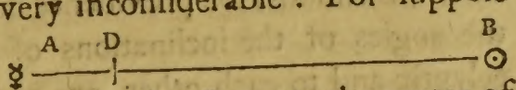
Fig. 5



APPENDIX.

IF we ſuppoſe all the ſolid globes of the ſolar Syſtem to be annihilated, their atmoſpheres remaining; the power of gravity, which had theretofore condenſed them round their reſpective orbs, ceaſing, they would immediately expand themſelves *quaquaverſum*, in conſequence of the mutual repellency of their particles, till the whole ſpace in which the bodies of the Syſtem had revolved, was equally filled with the fluid, and when its denſity became equal in every part, the whole would be at reſt.

So, *vice verſa*, if we ſuppoſe ſuch a fluid, to have been the firſt material ſubſtance in the order of creation, equally diffuſed, in that rarefied ſtate, throughout the mundane ſpace; next after it, the ſeveral maſſes of the Sun, Planets and Comets, nearly about the ſame time with each other: This fluid, though its particles are in a ſtate of mutual repulſion, yet as they are in the common ſtate of gravitation to the other bodies of the Syſtem, would be attracted by the ſeveral globes, every particle moving towards that globe, which ſhould have the balance of attraction in its favour.

Mercury's atmoſphere, by reaſon of its neighbourhood to the Sun, and the ſmallneſs of his globe would be leaſt of all and very inconſiderable: For ſuppoſe a right line A B. 

drawn from the center of the Sun to the center of *Mercury*, to be ſo divided in D, that the part next the Sun may be to the part next *Mercury* in the ſubduplicate ratio of the quantity of matter in the Sun

Sun to the quantity of matter in *Mercury*; every particle between D and B would deſcend to, and be condenſed round the Sun, and thoſe only between D and A to *Mercury*; and it appears by computation that DB : DA : : 3693 : 1 nearly, and in all oblique directions the particles, whoſe diſtances from the Sun and Mercury were proportionably greater or ſmaller, would deſcend to, and condenſe round one or the other; unleſs drawn aſide by ſome other Planet: What is here ſaid of *Mercury*, is equally applicable to the other Planets; and as the attraction of the Sun is vaſtly greater than the united attractions of all the Planets together; ſo, in every part of the Syſtem, where the attractive power of the Sun might be greater than that of any neighbouring Planet; the fluid occupying that part of the ſpace, would deſcend and join the Sun's atmoſphere; while the reſt would be continually condenſing round the Planets, till at length the ſeveral globes would be accommodated with their proper atmoſpheres, when the Heavens would be left a perfect vacuum for the various bodies to revolve in, without the leaſt reſiſtance.

If the Comets be ſuppoſed to have been created and projected in their ſeveral orbits, at their aphelia, or at their greateſt diſtances from the Sun, it may be eaſy upon this hypotheſis to account for their having atmoſpheres ſo much exceeding thoſe of the Planets in their dimenſions, for providence has ſo ordered it, that the angles of the inclinations of their orbits to the eclyptic and to each other are generally very great, and their motions are directed to all parts of the Heavens indiſcriminately, whereby their diſtances from the Planets and from each other at their aphelia,

are

are great beyond human conception; conſequently they were at liberty to ſhare amongſt themſelves, without any moleſtation from the Planets, all that part of the fluid, which filled the vaſt ſpaces of the Syſtem, without the planetary regions; therefore if the hypotheſis be granted, they muſt neceſſarily have ſuch atmoſpheres, as, in fact, we find they have, and which, in their deſcent through the planetary ſpheres, are, by the (ſuppoſed) repulſion of the Sun's atmoſphere, driven to ſuch aſtoniſhing diſtances behind them, as occaſion may require. Thoſe whoſe aphelion diſtances were greateſt, being more ſolitary, would condenſe round them the greateſt atmoſpheres, and ſuch, their greater diſtances from the Sun would require, upon the foregoing principles, to make them comfortable habitations. As the lengths of their tails would probably, at equal diſtances from the Sun, be proportional to the quantities of this repellent matter contained in their atmoſpheres reſpectively, it may not be impoſſible to form a rational conjecture of their real aphelion diſtances, by obſerving the apparent lengths of their tails, when at equal diſtances from the Sun, in their deſcent, and thence computing their real lengths, and comparing thoſe whoſe aphelion diſtances are unknown with thoſe which are already determined; and as nearly as we can by this method come at their greateſt diſtances from the Sun, ſo nearly may we (by comparing their computed trajectories, with thoſe diſtances,) determine their mean diſtances and periodic revolutions. But this is humbly ſubmitted to better judges, and is deſigned only as a hint for future inquiries.

F I N I S.